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An elective chemistry course is designed to be equally valuable to both future scientists and non-scientists. The emphasis is placed on fundamental concepts and relationships rather than on descriptive and applied chemistry. Major objectives are: to survey the present state of chemical knowledge; to examine in some depth central chemical concepts including structure, bonding, and energy changes; to acquaint students with the experimental method and its particular application in chemistry; and to appreciate the power of modern chemistry in helping man control his environment. Chemistry units outlined are: fundamentals of chemistry, periodic relationships, motion and dynamic equilibrium, inorganic reactions, organic reactions, and nuclear reactions. Each study guide consists of: an introductory page which explains the content and integrating ideas which form the framework of the unit; a chart of specific suggestions for teaching the unit; and resource sheets of various kinds. Some of the resource sheets give subject matter needed to develop the unit but not available in the textbook. Others present detailed directions for demonstrations and experiments. The final resource sheet provides suggestions for independent study in each unit.							
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SENIOR
HIGH SCHOOL
CURRICULUM GUIDE

CHEMISTRY

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BALTIMORE COUNTY PUBLIC SCHOOLS

BALTIMORE COUNTY PUBLIC SCHOOLS

A Course of Study
in
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1961

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FOREWORD

As part of a county-wide program to provide curriculum materials for gifted and superior students, the chemistry teachers of Baltimore County made a comprehensive study during the school year 1958-1959 to determine what should be included in a high-level chemistry course. Their findings served as background material for a committee which developed a Preliminary Outline in Chemistry for Superior and Gifted Students during the 1959 Summer Workshop. This course, which emphasized fundamental concepts and unifying relationships, was tried out by ten different teachers in eight schools during the two school years from 1959 to 1961.

The experiences of the teachers experimenting with the new course indicated that the conceptual approach to high school chemistry had validity for regular classes as well as for high-ability students. This, coupled with the fact that the regular course had not been revised since 1950 and thus failed to include many significant modern developments, pointed up the need for a reorganization of the total chemistry program.

After a series of meetings of all chemistry teachers the present program for both regular and high ability classes was developed fully by a committee during the 1961 Summer Workshop. This committee acknowledges its indebtedness to the 1959 Committee which, in turn benefited from the help of many interested individuals including Dr. Belle Otto, Chairman of the Natural Sciences Division of Goucher College and Dr. Louise Kelley, former Chairman of the Chemistry Department of the same institution.

A special word of thanks is also expressed to all of the chemistry teachers in the Baltimore County schools and to Miss Linda Almony, who was responsible for typing the materials.

THE CHEMISTRY COMMITTEE

July, 1961

M. Polk Roberts, Chairman
Helen E. Hale, Supervisor

THE SECONDARY SCHOOL SCIENCE PROGRAM

The science curriculum for grades seven through twelve is based on a belief in the necessity for the fullest possible development of the individual in an evolving democracy and as a responsible world citizen. The impact of today's science on our intellect and emotions not only forces us to believe in the necessity for understanding ourselves and each other but also presents clearly our individual responsibility for contributing to human betterment. Every citizen should have a knowledge of the role of science in today's world and an appreciation of the necessity for thoughtful planning for the present and future uses of technological advances. The proper utilization of scientific discoveries is of vital importance for the very existence and perpetuity of mankind.

Throughout life man interacts with his environment and has progressed only as he has learned to control certain basic aspects of this environment or adapt himself to them. The science program must concern itself with those ways of thinking and doing which help adolescents to understand themselves and their surroundings so that they can make increasingly satisfactory adjustments. Scientific understandings and experiences may contribute markedly to the dual goal of maximum self-development and responsible group living.

The major objectives for the high school science program are:

1. To acquire those scientific facts, concepts, and generalizations which lead to a better understanding and appreciation of the universe

Development of understandings and appreciations depends upon the mastery of certain essential facts, concepts, and generalizations, the choice of which should be determined by the ability and maturity levels of the pupils. As the pupils extend their understandings, they will develop an appreciation of both the complexity and orderliness of the universe.

2. To develop skill in using many resources for solving problems.

In the early grades the problems will relate to the immediate environment and interests of the pupils. Facility in problem solving will be increased as the pupils learn to use controlled experiments, field study, reference materials, visual aids, and interviews more and more effectively.

3. To understand the variety of methods employed by the scientists

Laymen have a tendency to picture the scientist as a person who comes to startling conclusions through a stereotyped procedure called the scientific method. Pupils should come to realize that scientists are human beings who employ many different procedures in arriving at conclusions. They should be made aware of the importance of the poorly-understood intuitive "flash" as well as the value of simple observation and classification, trial and error procedures, controlled experiments, and accidental discoveries.

4. To appreciate the tentative nature of scientific data and conclusions

Pupils tend to accept without question scientific theories and principles. This wholehearted acceptance should be tempered by the realization that accepted principles and theories must sometimes be modified or rejected when new scientific data are acquired. Pupils should be taught to detect the assumptions underlying many scientific conclusions, to use pertinent information, and to withhold judgment until all possible evaluations of data are made.

5. To facilitate effective communication of scientific ideas

The use of a variety of learning experiences should enable the pupil to acquire proficiency in reading, writing, observing, recording, and reporting science material. In a broader sense, this implies the need for free communication of ideas among the world's scientists.

6. To nurture the natural scientific interests of each individual

The teacher should stimulate natural scientific interests of the pupil through varied teaching techniques, enrichment programs, and the development of a general classroom atmosphere conducive to learning. Where appropriate, he should provide pupils with specific experiences related to science careers and hobbies.

7. To develop an awareness that man's ability to modify his environment is limited by his understanding of its nature

Man can exercise some control over certain factors in his environment. He has, for example, learned to harness the sun's energy, to increase his own life expectancy, to develop new plant and animal forms, to release the energy within the nucleus of the atom, and in a small way, to modify the weather. Further environmental control is dependant upon increased knowledge.

8. To appreciate the contributions of scientists

In order to appreciate that science is an on-going enterprise, pupils should learn about modern contributors as well as the historical figures who have been responsible for the major developments in science and should be given the experience of meeting and talking with practicing scientists in their own or nearby communities.

9. To develop an understanding of the interrelatedness of the various sciences

More and more, the divisions among the scientific disciplines are disappearing. Pupils should learn not only how each science depends upon every other science including mathematics, but also how difficult it is to assign certain areas of investigation to a particular science. A case in point is medical research.

10. To develop an awareness that science is but one factor which contributes to man's well-being

There is an increasing danger that scientific and technological advances may be made at the expense of advances in the social sciences and the arts. A balance is imperative. There is a further danger that students will view science in a narrow, utilitarian sense and fail to derive esthetic satisfactions from the logic and beauty of ideas.

11. To make the pupil aware of his social and moral responsibility to mankind

The questionable use of some scientific discoveries has caused man to lose many of the benefits he should have derived from the concomitant investigations. It is the duty of the teacher to make the pupil aware of his obligation to control the practical application of scientific discoveries and to utilize them for the betterment of mankind.

THE CHEMISTRY PROGRAM

Chemistry, as one of the natural sciences recommended for all academic students, is an integral part of the general education program. This course is, therefore, designed for all students who elect chemistry and should be equally valuable to both future scientists and non-scientists.

A rising tide of opinion supports the view that descriptive and applied chemistry contribute less to the nonscientist's understanding of physical phenomena and of the true nature of the scientific endeavor than a course emphasizing fundamental concepts and relationships. It was the intention of the Chemistry Committee to build a course with the latter emphasis where descriptive aspects of chemistry are dealt within the framework of a conceptual organization of content rather than as ends in themselves.

The general education value of such an approach is not its only justification. Perhaps more important is the fact that chemistry is approaching maturity as a science; that is, more integrating theory is constantly becoming available to tie the bewildering array of factual information into a valid conceptual scheme. Without unifying theory no modern chemistry course could achieve even a superficial survey of chemical knowledge.

Two major national groups, the Chemical Education Materials Study Committee and the Chemical Bond Approach Project have undertaken to improve the high school chemistry course. Wherever their materials have seemed useful they have been included. The general organization of the course, however, is based primarily on the outline prepared by a committee of chemistry teachers in a previous Baltimore County curriculum workshop. The trend toward a more theoretical approach to chemistry is apparent in all of these pioneering courses.

The objectives of chemistry stem from the general purposes for secondary school science listed on the preceding pages. Succinctly stated, they are:

1. To survey the present state of chemical knowledge
2. To examine in some depth central concepts in chemistry including structure, bonding, and energy changes
3. To acquaint students with the experimental method and its particular application in chemistry
4. To understand the tentative nature of scientific knowledge and the limitations of the experimental method
5. To appreciate the power of modern chemistry in helping man control his environment

USE OF THE COURSE OF STUDY

The content of the chemistry course has been organized into six large units. Teachers are asked to teach all of the units to both regular and high-ability classes with, however, a somewhat different emphasis for the two kinds of groups. There are, for example, topics, approaches to topics, and activities which are coded with an asterisk (*) to indicate that they are appropriate only for high-ability students. Others are coded with the symbol "#" to show that they are intended only for chemistry students of average ability.

Time Allotments

Taking cognizance of the variations in the program for students of differing abilities, the Chemistry Committee developed suggestions for time allotments for the units as follows:

Unit	Time in Weeks	
	Regular Classes	High-ability Classes
One	8	8
Two	6	5
Three	6	8
Four	8	8
Five	4	4
Six	4	3

It must be remembered that the committee members were merely making educated guesses and that other factors such as teacher and student interest may prevent strict adherence to the above schedule. Teachers will have to exercise their own judgment in this matter with the stipulation that all of the units should be included and that, if possible, they should be taught in the order in which they appear in the Course of Study.

Organization of the Units

Each unit has been developed in terms of a content outline which is presented and explained as the "Scope of the Unit." Teachers are urged to read the scope carefully several times in order to have clearly in mind the content and the one or two integrating ideas which the Committee established as the framework for each unit. This is of the utmost importance in Unit One where the concepts of structure and bonding and the nature of the scientific enterprise are themes not only for the unit but also for the entire course. It would be difficult to overemphasize the imperative that teachers become aware of the central ideas of the course and the various units, and that they teach directly for student understanding of these big ideas.

Specific suggestions for teaching the unit have been worked out in chart form. The suggested procedures are presented in a teachable sequence with supporting references noted in an abbreviated bibliographical form immediately to the right of each

activity. Complete bibliographical information including annotations for periodical articles and audio-visual aids is given at the end of the teaching suggestions.

The suggestions for both content and learning activities are far from exhaustive for any of the units; nor are they restrictive. Individual teachers will undoubtedly adapt and supplement the suggestions which the Course of Study offers.

Resource Sheets

Resource sheets of various kinds have been inserted at the end of each unit. Some of them give subject matter needed to develop the unit but not readily available in textbooks and references. Others present detailed directions for demonstrations and experiments not found in the manuals. The final resource sheet in each unit provides suggestions for independent study, including some long-range experimental and library research projects.

As teachers use the Course of Study they may add resource sheets of their own and make notations of other needed modifications. They will need to keep the bibliographies up-to-date, particularly the periodical listings. In sum, this is not a static document to be followed slavishly but rather the present status of a dynamic chemistry curriculum for the Baltimore County Schools.

UNIT ONE

FUNDAMENTALS OF CHEMISTRY

I. Scope of the Unit

Unit One has been developed with dual intent: 1) to present the concepts of structure and bonding on which the remainder of the course is based, and 2) to introduce and encourage a manner of thinking essential to scientific investigation. Because conscious and systematic use of experimentation is perhaps the distinctive contribution of science in the quest for knowledge, the unit begins with a series of laboratory activities. Deceptively simple materials are used on the one hand to review and extend the elementary skills of observing, handling materials, recording data, making calculations, and writing reports and on the other to teach some fairly sophisticated notions about the significance of observations, the role of assumptions, the importance of mental models, and other complexities of thought patterns and processes.

The limitations of the experimental approach are also considered; first those inaccuracies introduced by the limitations of human sensory equipment which can be partly reduced by training and experimentation, and then the fallibilities which cannot be corrected. The latter can be recognized and to a degree compensated for by the application of thought processes in gathering, handling, and interpreting experimental data.

Because of its central importance in all chemical processes atomic structure is introduced early in the course. To avoid disconcerting abstraction and overwhelming confusion the idea of structure may be tied firmly to a consideration of the first ten elements of the periodic table. It will be necessary to teach fundamental concepts of elements, particles, and forces as a basis for detailed consideration of the chemical atom. Also essential is the idea of a mental model since, at present, different models are used to account for different types of phenomena. Bonding is then introduced and it and structure are used as the logical base for teaching the mechanical skills of writing and balancing formulas and equations.

Fundamentals of Chemistry

I. Investigative techniques in chemistry and their limitations

A. Observation

1. Making accurate observations
2. Handling quantitative data
3. Learning the properties of some elements and compounds
4. Noting sense limitations

B. Laboratory tools

1. Measurement tools

- a. Review of metric system
- b. Measuring instruments
- c. Accuracy in measurement
- d. Units of measurement

2. Other laboratory tools

C. Chemical symbols

D. Thought processes

1. Indirect evidence
2. Induction-deduction
3. Mental models

E. Uncertainty of scientific knowledge

1. Accuracy and reliability; limit of error
2. Probability

II. Fundamental concepts

A. Elements

1. Historical background
2. Atomic theory

B. Particles

1. Historical experiments
2. Properties of particles

- a. Mass
- b. Size
- c. Charge
- d. Spin

3. Atoms

- a. Atomic number
- b. Mass number

C. Forces

1. Electromagnetic

- a. Coulomb's law
- b. Energy, wave length, frequency

2. Gravitational

3. Nuclear

III. Mental models of atomic structure

A. Bohr model

B. Orbital model

1. Quantum

2. Quantum numbers

- a. Permissible values
- b. Pauli Exclusion Principle

3. Quantum levels

- a. Order of filling
- b. Hund's rule
- c. Ground and excited states

IV. Bonding and electronegativity

A. Types of bonds

1. Electrovalent

2. Covalent

- a. Polar and non-polar
- b. Dative
- *c. Multiple

***3. Hydrogen**

4. Metallic

B. Formula writing

1. Oxidation numbers

2. Electron dot

C. Nomenclature

1. Traditional system

2. Stock system

D. Formula problems

1. Gram-atomic weight
2. Formula weight
3. Percentage composition
4. Gravimetric factor
5. Calculating empirical formula
6. Calculating gram formula weight
7. Calculating true formula

V. Equations

A. Reaction types

1. Redox
 - a. Combination
 - b. Decomposition
 - c. Single displacement
2. Metathesis

B. Equation problems

1. Weight-weight
2. Volume-volume
3. Mixed

II. Suggested Procedures

CONTENT	TEACHING SUGGESTIONS	REFERENCES
I. Investigative techniques in chemistry and their limitations A. Observation 1. Making accurate observations 2. Handling quantitative data 3. Learning the properties of some elements and compounds	Have students carry out laboratory activities and observe demonstrations which will help them to develop competence in techniques and strategies for investigations: 1. Experiment with a burning candle as suggested in the CHEM Study. 2. Do a laboratory exercise such as the MCA Bunsen burner experiment in which data can be handled quantitatively and graphed. *3. Teach the graphic method for showing fundamental functional relationships by having students graph a one-constant function ($y=kx$), a two-constant function ($y=k_1x+k_2$), and an inverse relationship ($k=xy$). 4. Familiarize students with some of the first few elements in the periodic chart by demonstrating the properties of the following materials: hydrogen, oxygen, sodium, carbon, magnesium, calcium, chlorine, aluminum, sulfur, and mercury. Ask students to record the properties and then to group the elements on the basis of their observed properties.	CHEM Study Laboratory Manual Volume I pp. 1-1 to 1-3 MCA Scientific Experiments in Chemistry pp. 7-8 De Rose Principles of Measurement pp. 45-54

CONTENT	TEACHING SUGGESTIONS	REFERENCES
4. Noting sense limitations	5. Assign to each student some harmless and unlabeled material such as soap, carbon, water, ethyl alcohol, vinegar, glycerine, vaseline, salt, sugar, sulfur, copper II sulfate, paraffin, moth crystals, aluminum, magnesium, iron, lead, copper, and a powdered mixture of iron and sulfur. (The use of a handbook may be taught in relation to this activity.) Require each student to present all the evidence by which he made his identification. Summarize with the class the properties involved in the identifications. Play part of the recording, "Science of Sound" to show the range of audio frequencies. Discuss ultrasonic and infrasonic frequencies and differences among individuals in their ability to detect sounds. Post a chart showing the electromagnetic spectrum. Point out the small range of visible radiations compared to the complete spectrum. Discuss the need for instruments which extend the human senses. Present various examples to show that human senses are fallible in regard to perception of motion; e.g. the motions of the earth, the sensations experienced by an observer when a train passes, and the state of weightlessness. Present some of the examples given by Andrews and Kokes which show the tremendous range of size in the universe and the limitations in our understanding of the atom brought about by its small size and large numbers.	Hodgman (ed.) <u>Handbook of Chemistry and Physics</u> Bell Telephone Laboratories "Science of Sound" Welch Company <u>Chart of Electromagnetic Radiations</u> Andrews and Kokes <u>University Chemistry Volume I</u> pp. 1-22

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Laboratory tools 1. Measurement tools a. Review of metric system b. Measuring instruments c. Accuracy in measurement d. Units of measurement	Prepare students for a laboratory exercise on density and specific gravity by reviewing the metric units of length, mass, and volume and the centigrade temperature scale. Demonstrate the use of the meter stick, beam balance, and simple volumetric equipment. Provide practice as needed. Teach material on the nature of measurement, significant figures, and errors in measurement and provide practice exercises. Stress the value of experimental notation and give practice as needed. Demonstrate the use of the analytical balance. Discuss the meanings of accuracy and precision as they relate to the analytical balance. Arrange to have individual practice using the balance. Show the film, "The Analytical Balance and Its Use." Discuss the importance of units and give students practice in handling units in simple calculations. Avoid use of any system other than the metric.	De Rose <u>Op. cit.</u> pp. 1-14 Markham and Reilley <u>A Laboratory Manual for General Chemistry</u> pp. 7-10, 21-36 Sienko and Plane <u>Experimental Chemistry</u> pp. 31-38 Weisbruch <u>Semimicro Laboratory Exercises</u> pp. 15-18 De Rose <u>Op. cit.</u> pp. 15-30 Baltimore County Film #590.83

CONTENT	TEACHING SUGGESTIONS	REFERENCES
CONTENT 2. Other laboratory tools C. Chemical symbols	*Use the dimensional analysis chart at the end of Resource Sheet 1 as the basis for teaching the meaning of fundamental and derived units. Teach the use of other laboratory tools and procedures as the need arises. Include glass working, handling of reagents, gas-generating and collecting, distillation, centrifugation, precipitation and filtration, crystallization, and selective adsorptions. Divide the class into groups for a laboratory session in which they prepare and observe the properties of oxygen, hydrogen, carbon IV oxide, ammonia, nitrogen IV oxide, etc. Have groups report and demonstrate their preparations to the class. <u>In all laboratory exercises stress safety precautions.</u> Post and ask the students to memorize the symbols for the first 20 elements. Explain the derivation of the symbols. Add others as the course proceeds.	Resource Sheet 1 Andrews and Kokes Op. cit. pp. 67-71 Dull, et al. Laboratory <u>Experiments in Chemistry</u> pp. 1-8, 15-18, 45-47, 93-96, 105, 111-114, 119-121 Markham and Reilley Op. cit. pp. 11-14 Weisbruch Op. cit. pp. 1-14, 31-40, 105-140, 159-162 Young <u>Practice in Thinking</u> pp. 1-30 Sienko and Plane Op. cit. (manual) pp. 1-23, 109-113

CONTENT	TEACHING SUGGESTIONS	REFERENCES
D. Thought processes 1. Indirect evidence	Pass around the class several black boxes each containing a different object. Ask students to predict as much as they can about each object, giving reasons to support their predictions. Then ask, "What color is the object?" Discuss the importance and limitations of indirect evidence.	Resource Sheet 2 CBA Chemistry Laboratory, <u>Volume I</u> p. 10
2. Induction-deduction	Present the thought experiment developed by the CHEM Study Project as an illustration of induction and deduction. Have students cite examples of their use of these methods in their ordinary experiences.	CHEM Study Op. cit. pp. 1-4 to 1-6
3. Mental models	Use molecular models to form a water molecule. Show that, although the model accurately reproduces certain features of a true water molecule, it is <u>not</u> a water molecule. Discuss the distinction between real objects and names or symbols used to represent them. Give numerous examples. Throughout the course continue to develop and extend the idea of mental models.	
E. Uncertainty of scientific knowledge *1. Accuracy and reliability; limit of error	*Teach students the distinction between accuracy and reliability. Review and extend the material on kinds of errors and determination of limit of error or uncertainty.	De Rose Op. cit. pp. 31-43
2. Probability	Discuss the relationship of theoretical mathematics to physical reality and point out the limitations of mathematics. As an approach to probability ask students to carry out a coin-	

CONTENT	TEACHING SUGGESTIONS	REFERENCES
II. Fundamental concepts A. Elements 1. Historical background 2. Atomic theory	tossing or card-drawing activity. Discuss probability as it relates to experimental results. Emphasize that all scientific inductions are probabilities. Have several students investigate and report to the class on the historical background of some of the first ten elements and their compounds such as Priestley's and Scheele's discovery of oxygen and Cavendish's discovery of hydrogen. Have students develop for the class: 1. Early ideas as to what matter is. 2. Dalton's ideas as to what matter is. 3. Present ideas as to what matter is. Have students compare the ideas and list their similarities and differences.	Commission on Mathematics, College Entrance Examination Board <u>Introductory Probability and Statistical Inference for Secondary Schools</u> pp. 43-130 Dull, et al. <u>Modern Chemistry</u> pp. 84-110 Bradbury, et al. <u>Chemistry and You</u> pp. 30-38, 55-68 Carleton and Carpenter <u>Chemistry for the New Age</u> pp. 64-70 Garrett, et al. <u>Chemistry</u> pp. 44-77 Dull, et al. <u>Op. cit. (text)</u> pp. 40-41

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Particles 1. Historical experiments	Develop the concept that matter is not continuous. Show the filmstrip "The Atom." Use a Crookes cathode ray tube to simulate the discovery of the electron. Show that: 1. If an object of considerable thickness is placed in the path of the cathode rays, a shadow will be cast on the glass opposite the cathode. Cathode rays travel in straight lines. 2. If cathode rays are passed through a magnetic field, paths of the rays are curved. The shadow moves as the field is varied. Cathode rays are electrically charged. Rays are deflected from negative charge toward positive charge. Cathode rays are negatively charged. 3. Cathode rays turn small pin-wheels in their path suggesting that the electron is a particle having mass.	Bradbury, et al. <u>Op. cit.</u> pp. 123-124 Carleton and Carpenter <u>Op. cit.</u> pp. 62-63 Life Filmstrip "The Atom" Hiller and Herber <u>Principles of Chemistry</u> pp. 11-15 Shamos (ed.) <u>Great Experiments in Physics</u> pp. 216-231 Ibid. pp. 238-249

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	Use the Shamos articles, "The Electron" and "The Elementary Electric Charge" for student reports in developing this topic. Have a student report on Becquerel's discovery of radioactivity to support the concept that atoms have internal structure. Give a lecture, illustrated by diagrams of a cathode ray tube with a perforated cathode, to explain the discovery of and name for the proton. Begin with Goldstein's discovery in 1886 of canal rays followed by J. J. Thomson's determination of the ratio of charge to mass (e/m) showing that the positive particle within the atom weighs about the same as the hydrogen atom. End with Rutherford's naming of the particle in 1920. The Scientific American article, "The Birth of the Nuclear Atom" provides excellent information to use in presenting Rutherford's classic experiment in which alpha particles shot at gold foil bounce back indicating a positively charged, dense nucleus. Rutherford's own words clinch the concept. "It was almost as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you." Have a student report on the speculations concerning the existence of a neutral particle within the nucleus and the discovery twelve years later in 1932 by Chadwick, using "The Neutron" article from Shamos.	Markham and Smith <u>General Chemistry</u> <u>pp. 140-146</u> Sienko and Plane <u>Chemistry</u> <u>pp. 33-45</u> Scientific American <u>Vol. 195, No. 11</u> <u>pp. 93-107</u> Sienko and Plane <u>Op. cit. (text)</u> <u>p. 41</u> Markham and Smith <u>Op. cit.</u> <u>p. 143</u> Shamos (ed.) <u>Op. cit.</u> <u>pp. 266-280</u>

CONTENT	TEACHING SUGGESTIONS	REFERENCES																				
2. Properties of particles	Explain how an uncharged particle can be discovered in a cloud chamber. Use a thought experiment to explain the path that appears after the collision of an electron or proton with an unseen particle.	Hogg, et al. Physics and Chemistry pp. 336-339																				
a. Mass	Teach the difference between mass and weight. Use examples such as: 1. The weight of a 100-gram object on earth becomes 16.67 grams on the moon but the mass remains the same. 2. At a certain point in space an astronaut become weightless but not without mass. 3. Weight increases as you approach the surface of the earth but mass does not.																					
b. Size	Compare mass and weight units.																					
c. Charge	Ask a committee of students to make simple models of a proton, neutron, electron and to label each as to mass, size, charge, and spin. Have all students make a chart summary of the data about these three elementary particles.	Scientific American Vol. 197, No. 7 pp. 72-92																				
d. Spin		Sienko and Plane Op. cit. (text) pp. 33-46																				
	ELEMENTARY PARTICLES <table><thead><tr><th>Particle</th><th>Mass</th><th>Size</th><th>Charge</th><th>Spin</th></tr></thead><tbody><tr><td>Proton</td><td></td><td></td><td></td><td></td></tr><tr><td>Neutron</td><td></td><td></td><td></td><td></td></tr><tr><td>Electron</td><td></td><td></td><td></td><td></td></tr></tbody></table>	Particle	Mass	Size	Charge	Spin	Proton					Neutron					Electron					Markham and Smith Op. cit. pp. 89-91, 104-110
Particle	Mass	Size	Charge	Spin																		
Proton																						
Neutron																						
Electron																						

CONTENT	TEACHING SUGGESTIONS	REFERENCES
3. Atoms a. Atomic number	If different values are found in different references make use of this to show the importance of using a variety of sources. Spin can be represented diagrammatically by means of the fraction and arrows. Solutions of the Schroedinger wave equation result in the number $+\frac{1}{2}$ for the spin of an electron. Refer to the gold foil experiment from which Rutherford was able to make important inferences about the nature of the nucleus and surrounding electrons. Have a student report on Moseley's use of x-rays to determine the atomic numbers of elements and the use of atomic numbers to place elements in periodic order.	Dull, et al. <u>Op. cit. (text)</u> <u>pp. 40-54</u> Gilreath <u>Fundamental Concepts of Inorganic Chemistry</u> <u>pp. 102-105</u> Markham and Smith <u>Op. cit.</u> <u>pp. 89-90</u> Sienko and Plane <u>Op. cit. (text)</u> <u>p. 45</u> Markham and Smith <u>Op. cit.</u> <u>pp. 144-145</u> Gilreath <u>Op. cit.</u> <u>pp. 76-79</u>

CONTENT	TEACHING SUGGESTIONS	REFERENCES
b. Mass number	Teach the concept of mass number and distinguish between mass numbers of isotopes and average atomic weight. Have students practice finding the number of protons, electrons, and neutrons an atom possesses by use of the atomic number and mass number.	
C. Forces 1. Electro-magnetic a. Coulomb's law	Introduce Coulomb's law as a mathematical statement of relationships already well known to the students. Like charges repel, unlike charges attract. For able classes show how the mathematical statement expresses this concept quantitatively. Include units. Use a chart of electromagnetic radiations to develop the relationship of wave length, frequency, and energy. Explain how electromagnetic radiations provide one means of studying atomic structure. The law of photochemical equivalence should be mentioned with classes of high ability. See Resource Sheet 3 for an exposition of these relationships.	Andrews and Kokes Op. cit. pp. 56-58
b. Energy, wave length, frequency	Explain the law of universal gravitation and its quantitative expression. Relate it to Coulomb's laws by showing the inverse square relationship.	Andrews and Kokes Op. cit. pp. 46-56 top Resource Sheet 3
2. Gravitational 3. Nuclear	Point out that forces within the nucleus cannot be explained in terms of either of the above inverse square relationships. Mass defect, neutron-proton ratio, and the meson should be mentioned, but discussed in detail only in high ability classes. The Bethe article, "What Holds the Nucleus Together?" is an excellent reference.	Hogg, et al. Op. cit. pp. 332-344 Scientific American Vol. 189, No. 9 pp. 58-63

CONTENT	TEACHING SUGGESTIONS	REFERENCES
III. Mental models of atomic structure A. Bohr model B. Orbital model 1. Quantum	Have students use the direct vision spectroscope to look at a white light source and flames of suitable metallic salts such as sodium, potassium, and copper. It is apparent that much of the content outlined in III will be mentioned briefly to regular classes but developed in some depth with high ability groups. Describe the spatial arrangement of the three fundamental particles already studied as presented by the Bohr model and modified in the Bohr-Sommerfeld model. If a three-dimensional model of some sample element is available have students examine this. If none is available have pupils build such a model. Explain the limitations of the Bohr-Sommerfeld model and, at a level appropriate to the ability of the class, show how the Heisenberg Uncertainty Principle and Schroedinger Wave Equations provide the best available mental model of the atom. For interested students review the basic idea of electromagnetic radiations and show how this information is used in spectrographic identification of elements. Show students absorption and emission spectra and explain how these help us to locate electrons in energy levels.	Garrett, et al. <u>Op. cit.</u> <u>pp. 85-91</u> Hiller and Herber <u>Op. cit.</u> <u>pp. 49-53</u> Nebergall and Schmidt <u>General Chemistry</u> <u>pp. 38-48</u> Welch Company <u>Spectrum Chart</u> Sienko and Plane <u>Op. cit. (text)</u> <u>pp. 49-63</u>

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Quantum numbers a. Permissible values b. Pauli Exclusion Principle 3. Quantum levels a. Order of filling b. Hund's rule	Discuss with all students the quantum numbers n (principal) and l (azimuthal) quantum numbers. With interested students include the m (magnetic) and s (spin) quantum numbers. State the Pauli Exclusion Principle and show how it makes use of the four quantum numbers; that is, no two electrons in the same atom can have all four quantum numbers the same. Present "ground rules" 2 and 3 as given in Resource Sheet 4 and develop with students a diagram like the one in Resource Sheet 5. Present "ground rule" 4 as given in Resource Sheet 4 and develop with students a diagram like the one in Resource Sheet 6. Give students order of filling of s, p, d, and f orbitals as shown in the diagram at end of Resource Sheet 4. Show students that line diagrams are useful for indicating relative energies of principal quantum levels but that another type of graphic presentation is needed to show maximum multiplicity (Hund's rule) in sub-levels. Have students complete a table showing electron configuration of elements 1-20:	Eichinger <u>The Electron Chart</u> Resource Sheets 4, 5, 6 Eichinger <u>Op. cit.</u> p. 8 Sanderson <u>Chemical Periodicity</u> pp. 26-27

CONTENT	TEACHING SUGGESTIONS	REFERENCES																	
	TWO DIFFERENT SYSTEMS FOR SHOWING ELECTRON CONFIGURATION <table><tr><th colspan="2">Element</th><th rowspan="2">Atomic Number</th><th colspan="3">Electron Population</th></tr><tr><th>Name</th><th>Symbol</th><th>K n=1</th><th>L n=2</th><th>M n=3</th></tr><tr><td>Example Oxygen</td><td>O</td><td>8</td><td>1s² (↑↓)</td><td>2s² (↑↓) 2p² (↑↓)</td><td>2p¹ (↑)</td></tr></table> Use the Energy Level Board described in Resource Sheet 7 to develop the meanings of quantized energy, line spectra, orbitals, spin, incomplete orbitals, and penetrating effect. Have the pupils draw line diagrams showing jumps giving rise to the different spectral lines of hydrogen. Use the Energy Level Board described in Resource Sheet 7 to build up the electron configurations for atoms having successive atomic numbers. Allow the pupils to use the board as a drill to show the arrangement of electrons in designated atoms. *Have high ability students write quantum numbers for each electron as orbitals are occupied.	Element		Atomic Number	Electron Population			Name	Symbol	K n=1	L n=2	M n=3	Example Oxygen	O	8	1s ² (↑↓)	2s ² (↑↓) 2p ² (↑↓)	2p ¹ (↑)	Garrett, et al. Op. cit. two plates preceding Resource Sheet 7 Eichinger Op. cit. pp. 31-32
Element		Atomic Number	Electron Population																
Name	Symbol		K n=1	L n=2	M n=3														
Example Oxygen	O	8	1s ² (↑↓)	2s ² (↑↓) 2p ² (↑↓)	2p ¹ (↑)														

CONTENT	TEACHING SUGGESTIONS	REFERENCES
c. Ground and excited states IV. Bonding and electronegativity A. Types of bonds 1. Electrovalent	*Have the pupils write the electron configurations of several elements with atomic numbers between 21 and 31. Use the quantum theory to explain the variations in filling orbitals as "3d" orbitals are occupied. Apply to the filling of "4d" and "4f" orbitals. *Discuss with the class, or have a capable student present, the effect of added protons in the nucleus of an atom on the energy of the electrons. Use this to explain the overlapping of 3d and 4s energy levels. Referring to spectral lines for hydrogen and other simple elements show what happens when electrons are displaced from their ground position to higher energy levels. Introduce the concept of electronegativity and relate electronegativity to structure and bonding. Present electrovalent bonding. Use Lewis structures to show the loss and gain of electrons. Stress the formation of ions and the formation of compounds by the attraction of opposite charges.	Markham and Smith Op. cit. pp. 181-183 Sienko and Plane Op. cit. (text) pp. 78-95 Dull, et al. Op. cit. (text) pp. 65-67 Bradbury, et al. Op. cit. pp. 152-154

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Covalent a. Polar and non-polar b. Dative	Develop the idea of covalency using the electronegativity charts. Indicate the position of the element and the relationship of the position on the chart to the formation of polar covalent and non-polar covalent compounds. Using a suitable group of elements, have the students predict, on the basis of electronegativity, whether the compound formed will be electrovalent, polar covalent, or non-polar covalent. Stress that many bonds are really intermediate in character, few being purely electrovalent or covalent. Examples of elements that could be used are: Al + F, Al + Cl, Al + O, H + O, H + Cl, Li + Br, C + F, Ca + I, Ca + C, C + O, Si + O, P + O, Sn + Cl, Sn + O, Ti + O, P + S, Cl + Cl. Pose such questions as: 1. Which of the bonds formed is most ionic in nature? 2. Which of the bonds formed is the most non-polar covalent? 3. Explain the dipolar nature of the H₂O molecule by examining its structure. Using several simple compounds such as SO₃, C₂H₂, C₂H₄, discuss double and triple covalent bonding. Use the examples in Sackheim to develop the nature of the	Sackheim <u>Problem Solving in General Chemistry</u> pp. 84-92 CBA Op. cit. (text) pp. IV-69 to IV-72 Garrett, et al. Op. cit. pp. 100-111 Dull, et al. Op. cit. (text) pp. 68-70

CONTENT	TEACHING SUGGESTIONS	REFERENCES
coordinate bond. Stress the understanding that, once a dative bond is formed, in character it is no different from a regular covalent bond. The only difference is in the source of the electrons. *c. Multiple *Put a formula such as H_2SO_4 on the board. Ask students to indicate what type of bonding exists between H, S, and the four O atoms. Let them think about the problem for awhile. Then indicate the types of bonds as a group. Present more examples and develop reasons for multiple bonding. Give the students practice in recognizing and locating the positions of electrovalent, covalent, and dative bonds in multiple bond compounds. *3. Hydrogen *Using the difference in electronegativity of atoms as a starting point, develop the concept of the hydrogen bond. Discuss the difference between the protonic bridge and the hydridic bridge. Relate these hydrogen bonds to formation of polymers and to the high boiling points of the compounds in which protonic bridging occurs.		Sackheim Op. cit. p. 87 Castka <u>Chemistry Problems</u> p. 80 Sackheim Op. cit. pp. 88-90 Gould <u>Inorganic Reactions and Structure</u> pp. 31-33 Pauling Nature of the <u>Chemical Bond</u> pp. 449-504 Sanderson Op. cit. pp. 169-175 Gould Op. cit. pp. 31-33

CONTENT	TEACHING SUGGESTIONS	REFERENCES
4. Metallic B. Formula writing	Discuss the nature of the metallic bond. Base the discussion on the atomic structure of metals and relate the metallic bond to characteristic properties of metals. Use the electron cloud concept of the metallic bond. Show how the "loose" electrons would account for the conductance properties of metals. Make use of the diagrams in the Chemical Bond Approach textbook.	Pauling <u>Op. cit.</u> pp. 449-504 Sanderson <u>Op. cit.</u> p. 20 Garrett, et al. <u>Op. cit.</u> p. 112 CBA <u>Op. cit.</u> pp. IV-82, IX-219-222, viii CHEM Study <u>Op. cit.</u> Volume III pp. 25-12 to 25-15 Sanderson <u>Op. cit.</u> pp. 18-20 Gilreath <u>Op. cit.</u> p. 150

CONTENT	TEACHING SUGGESTIONS	REFERENCES
1. Oxidation numbers	Use the Energy Level Board described in Resource Sheet 7 to develop the meaning of the term, "oxidation number." Have the pupils use the board to show the electron configurations of elements that can acquire more than one oxidation state. Distinguish between valence and oxidation number. With high ability students the concept of coordination number could be presented. Show students how to use a table of oxidation numbers to find major and minor oxidation states of the elements. Point out elements having variable oxidation numbers and elements having invariable oxidation numbers. Either dictate or duplicate the conventions regarding the use of oxidation numbers in regard to ionic and molecular compounds. Demonstrate the use of the principle that the algebraic sum of oxidation numbers in a compound must be zero in writing formulas.	Resource Sheet 7 Castka Op. cit. p. 79 Merck Company Chart of the <u>Elements</u> Markham and Smith Op. cit. pp. 222-226 Sienko and Plane Op. cit. (text) pp. 107-110 Castka Op. cit. pp. 77-80 Dull, et al. Op. cit. (text) pp. 79-81
2. Electron dot	Demonstrate the use of the electron dot convention in formula writing.	

CONTENT	TEACHING SUGGESTIONS	REFERENCES
C. Nomenclature 1. Traditional system 2. Stock system D. Formula problems 1. Gram-atomic weight 2. Formula weight 3. Percentage composition	Have students do exercises on formula writing as a drill on oxidation number and electron dot methods. Have students read a reference on the naming of inorganic compounds. The Stock system has been officially adopted and its use is becoming more widespread. See Resource Sheet 8. Give students practice in naming acids, bases, salts, and oxides by both systems. Explain the relationship of relative atomic weight, absolute atomic weight, and gram-atomic weight in terms of Avogadro's number. Extend these relationships to formula weights and the concept of the mole. Have students practice calculating formula weights and percentage composition. Divide the class into groups. Have each group find the percentage of water in a different hydrate. Discuss the	Castka Op. cit. pp. 81-82, 87-90 Sackheim Op. cit. pp. 84-94 Ibid. pp. 25-30 Castka Op. cit. pp. 85-87 Resource Sheet 8 Castka Op. cit. pp. 131-134

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	laboratory session. Have the students suggest a method by which formulas of compounds could have been gotten before knowledge of electron configuration.	Dull, et al. Op. cit. (manual) pp. 57-58 Markham and Reilley Op. cit. pp. 133-135
4. Gravimetric factor	Show how gravimetric factors may be used in solving simple stoichiometric problems.	Castka Op. cit. pp. 134-135
5. Calculating empirical formula	Demonstrate and have students practice finding empirical formula, gram formula weight, and true formula for gases and non-volatile, soluble solids.	Ibid. pp. 136-147
6. Calculating gram formula weight	Have students do laboratory exercises in which they determine molecular weight by the depression of freezing point and the elevation of boiling point.	Markham and Reilley Op. cit. pp. 213-217, 223-226
7. Calculating true formula	Review the concept of heat and specific heat. Show how the law of Dulong and Petit can be used in predicting the atomic weight of many solid elements. Some students might profitably do graphic representations of the inverse relationship between atomic weight and specific heat or show that in an inverse relationship plotting the reciprocal of one of the functions results in a straight line.	Sienko and Plane Op. cit. (manual) pp. 103-108 Kieffer (ed.) Selected Readings in General Chemistry pp. 103-106

CONTENT	TEACHING SUGGESTIONS	REFERENCES
V. Equations A. Reaction types 1. Redox a. Combination b. Decomposition c. Single displacement 2. Metathesis B. Equation problems 1. Weight-weight	Show students how to write and balance chemical equations. Have them read references and then practice the technique until a reasonable degree of mastery is attained. Have students examine several references to find some general patterns and principles that aid in predicting reactions. Thermodynamic considerations can hardly be introduced at this point but the students might make a list showing products of combustion, acid-base, metal-acid, and other such reactions. Use the concept of oxidation number to show the difference between redox and metathetical reactions. Have students do laboratory exercises on activity of metals. Discuss the laboratory session. Introduce the mole, factor, and proportion methods of solving weight-weight problems. Have students practice solving problems. High ability students should use all three methods. Have a laboratory session in which the students determine the formula of copper sulfide by percentage composition and the experimental yield. Ask them to compare their experimental yield with the theoretical value.	Castka Op. cit. pp. 90-100 Sackheim Op. cit. pp. 31-33 Dull, et al. Op. cit. (text) pp. 161-174 Dull, et al. Op. cit. (manual) pp. 31-32 Castka Op. cit. pp. 148-153 Sackheim Op. cit. pp. 56-63 Dull, et al. Op. cit. (manual) pp. 33-34

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Volume-volume 3. Mixed	Have several students look up the historical background of volume-volume relationships and report on the contributions of Gay-Lussac, Cannizzaro, and Avogadro. Ask the class to record these contributions and to apply the information in the practice of volume-volume problems. Review the concept of molar gas volume which students will have encountered in determining the molecular weights of gases. Demonstrate how to solve problems in which first weight then volume is unknown. Have students practice solving such problems. As a means of summarizing the big ideas of the unit organize a panel discussion in preparation for which students have read each of the suggested books which treat the nature and philosophy of science. Before the panel reports, the teacher should confer with each panelist to be sure that he has identified the ideas in his book that pertain to the major concepts of the unit, particularly those covered in topics I, II, and III. Class discussion of the panel reports should be followed by a summary in which the major concepts in the unit and in the books are identified and listed.	Dull, et al. <u>Op. cit.</u> (text) pp. 184-201 Castka <u>Op. cit.</u> pp. 153-156 <u>Ibid.</u> pp. 156-161 Barnett <u>The Universe and Dr. Einstein</u> Coleman <u>Relativity for the Layman</u> Gamow <u>Mr. Tompkins in Wonderland</u> <u>One, Two, Three, Infinity</u> Hoffman <u>The Strange Story of the Quantum</u> Russell <u>ABC of Relativity</u>

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Harris, Sidney P., "Determining an Empirical Formula," Journal of Chemical Education Volume 37: 516-517, October 1960

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D. Audio-visual aids

1. Film

Analytical Balance and Its Use (sound, 18 minutes. Free, Central Film Library, Baltimore County Public Schools, Towson Senior High School, Towson 4, Maryland.)

2. Filmstrip

The Atom (55 frames, color, silent with captions. \$6.00, Life Magazine and Society for Visual Education, Inc., 100 East Ohio Street, Chicago 11, Illinois)

3. Recording

Science of Sound (33 1/3 rpm, 50 minutes. \$11.90, Bell Telephone Laboratories, New York, New York)

4. Charts

Chart of Electromagnetic Radiations, No. 4845
(58x42. \$10.00, W.M. Welch Scientific Company,
Chicago 10, Illinois)

Periodic Chart of the Elements (11x16. Free, Merck and Company, Inc., Rahway, New Jersey)

Resource Sheet 1

FUNDAMENTAL FORCES AND UNITS

The study of the behavior and structure of matter requires an understanding of energy and forces, the quantitative dimensions of these forces, and the relationship of these forces to distance and time. Mass, space, and time are the three fundamental units of measurement in science. Most other forms of measurement are simply derivations and combinations of these fundamental units. Energy in one of its forms is matter in motion. It requires work to change the motion of matter and matter in motion will do work. Both matter and energy have specific dimensions which are interrelated. The development of this interrelationship using c. g. s. measurement is as follows:

$$\text{work} = \text{force} \times \text{distance}$$

$$w = f \times d$$

The dimensions of force in the gravitational system are mlt^{-2} . These dimensions can be developed from Newton's second law of motion which states that the acceleration (change in velocity per unit time) of a body is directly proportional to the unbalanced force causing the acceleration.

$$\frac{f_1}{f_2} = \frac{a_1}{a_2} \quad \text{or} \quad f_1 a_2 = f_2 a_1$$

The force of gravity (weight) causes an acceleration of 980 cm/sec/sec or 980 cm/sec². Therefore, any other force, larger or smaller than the force of gravity, produces an acceleration proportionately larger or smaller than 980 cm/sec². In other words, the magnitude of forces acting on a body is compared to the magnitude of the force of gravity. The formula $\frac{f_1}{f_2}$ divided by f_2 equals a_1 divided by a_2 can be expressed more specifically as $\frac{f}{w} = \frac{a}{g}$.

Example 1. A body weighing 490 grams is accelerated with an unbalanced force of 490 grams. What is the acceleration of change in velocity?

$$\frac{f}{w} = \frac{a}{g} \quad \frac{490 \text{ g}}{490 \text{ g}} = \frac{a}{980 \text{ cm/sec}^2} \quad a = 980 \text{ cm/sec}^2$$

Example 2. Find the acceleration if the unbalanced force acting on a body weighing 490 grams is 245 grams.

$$\frac{f}{w} = \frac{a}{g} \quad \frac{245 \text{ g}}{490 \text{ g}} = \frac{a}{980 \text{ cm/sec}^2} \quad a = 490 \text{ cm/sec}^2$$

The unbalanced force causing acceleration in the second example is one half the weight of the body; therefore, the acceleration is one half the acceleration of gravity.

From the formula $\frac{f}{w} = \frac{a}{g}$ the formula $f = \frac{wa}{g}$ can be derived. The force of gravity varies inversely as the square of the distance. This means that the weight and acceleration of gravity decrease as one moves farther from the center of the earth and increase as one moves nearer. This change in magnitude of force and acceleration is in such proportion that a constant relationship is maintained. This relationship is shown by the formula $m = \frac{w}{g}$ which

indicates that mass is constant whereas weight varies with the gravitational force (g) acting on the body. Substituting m for $\frac{w}{g}$ in the formula $f = \frac{wa}{g}$

changes it to $f = ma$. Gravitational force then is really a product of mass and acceleration. Acceleration is change in velocity per given time. Velocity is change in position and direction per given time. It may also be stated that velocity is rate of speed in a given direction. The formula for velocity with respect to acceleration and time is $v = at$. In fundamental dimensions the formula is $v = \frac{l}{t}$. By rearrangement $a = \frac{v}{t}$ or in dimensional units $a = \frac{\frac{l}{t}}{t}$ or

$a = lt^{-2}$. The formula for force is $f = ma$. Substitution of lt^{-2} for "a" reduces the formula to the three fundamental dimensions of mass, distance, and time.

$$\underline{f = mlt^{-2}}$$

Since work is a product of force and distance, it too can be expressed in fundamental dimensions.

$$w = f \times d \quad w = ma \times d \quad w = mlt^{-2} \times l \quad \underline{w = ml^2t^{-2}}$$

Work differs from force by having an added dimension of distance.

Work has to be done to move a body away from the earth. This gives the body a property which did not exist before. It has gravitational potential energy from which the work put into its displacement can be recovered when it meets the earth. To move the body to a greater distance requires more work. This in turn gives the body greater potential energy which will do more work when it meets the earth. Gravitational potential energy then is the energy possessed by a body because of its position in relation to the earth.

$$\text{work} = \text{force} \times \text{distance} \quad \underline{w = ml^2t^{-2}}$$

$$\text{potential energy} = \text{force} \times \text{distance} \quad \underline{P. E. = ml^2t^{-2}}$$

Potential energy and work have the same three fundamental dimensions. At this point it can be seen that force, work and potential energy are related to each other in terms of mass, distance and time.

Kinetic energy refers to energy in motion. It is the type of energy that a body in motion possesses. It can be considered also as a measure of distance that a body in motion will continue to move against a constant retarding force. A body in motion is force moving through a distance and a force moving through a distance is work. Therefore, kinetic energy basically is work. $K. E. = f \times d$. However, a body in motion has velocity which may or may not be constant as the body continues to move and the distance through which the body moves depends on this velocity. Therefore, the components of distance in terms of velocity and time are used to determine kinetic energy. The elementary formula for distance is $d = rt$. R is the average rate of speed possessed by a moving body. If the speed is variable because of constant acceleration, the average velocity is one half of the difference between initial and final velocity.

$$\text{average velocity} = \frac{\text{final velocity} - \text{initial velocity}}{2}$$

If, however, a body is accelerated from a standstill position or zero velocity its average velocity is one half of the final velocity developed during a given period of time.

$$\text{average velocity} = \frac{\text{final velocity}}{2}$$

Velocity = acceleration x time; $v = at$ or $v/2 = at/2$. The formula $d = vt$ can be expressed as $d = v/2 \times t$ or $d = at/2 \times t$ which in its final form is $d = at^2/2$. Since $v = at$, $a = v/t$. Substitution of v/t for acceleration and of ma for force in the formula $K. E. = f \times d$ changes it to $K. E. = mv/t \times v/t \times t$ or $K. E. = \frac{mv^2}{2}$. This formula is used consistently in chemistry when referring

to kinetic energy of molecules. In terms of fundamental dimensions (length, mass, time) $K. E. = mv^2/2$ is $K. E. = m \times l/t \times l/t$ or $K. E. = ml^2t^{-2}$. The fundamental dimensions for $K. E.$ are the dimensions for work and potential energy.

Since thermal energy is a form of kinetic energy it has the same fundamental dimensions (length, time, mass) as work, potential energy and kinetic energy. Thermal energy is measured in calories and a calorie by definition is the amount of heat energy necessary to raise the temperature of one gram of water one degree centigrade. Specifically, heat energy is molecular motion. Therefore, heat energy or calories can be expressed as $mv^2/2$ or ml^2t^{-2} . Heat energy can be converted to mechanical energy to do work which is measured in terms of mass, length and time. (See chart for detailed relationships between calories and ergs.)

The relationship of power or rate of doing work to energy is derived as follows: $p = w/t = ml^2t^{-2}/t = ml^2t^{-3}$. Work is power x time; $w = p \times t$; $w = ml^2t^{-3} \times t$; $w = ml^2t^{-2}$.

Expenditure of energy for a period of time produces action by creating a force which moves a body through a distance during the time interval. Action is energy x time or action = $ml^2t^{-2} \times t = ml^2t^{-1}$. Force acting through distance and time is $f \times d \times t = mlt^{-2} \times l \times t = ml^2t^{-1}$. A force acting through a distance against a constant retarding force does so because it has kinetic energy; $f \times d = mv^2/2$ or $mlt^{-2} \times l = ml^2/t^2$ or ml^2t^{-2} . A force acting for a period of time against a constant retarding force does so because it possesses momentum; $f \times t = mv$ or $mlt^{-2} \times t = ml/t = mlt^{-1}$. Therefore, a force acting through both distance and time does so because it possesses kinetic energy and momentum. Work is accomplished, energy is expended and action is produced; $f \times d \times t = w \times t$ or $f \times d \times t = \text{energy} \times \text{time}$; $mlt^{-2} \times l \times t = ml^2t^{-2} \times t = ml^2t^{-1}$. Since action is work x time, work is action / time or $ml^2t^{-1}/t = \frac{ml^2t^{-1}}{t} = ml^2t^{-2}$.

A few specific fundamental units used in c. g. s. measurement are the dyne, erg and joule. The dyne is a measurement of force. It is the amount of force that will accelerate a one gram mass one cm. per sec.²; $f = ma$ or $f = mlt^{-2}$. The erg is a unit of measurement of energy which, by definition, is the force of one dyne acting through one cm.; $f \times d$ or $mlt^{-2} \times l = ml^2t^{-2}$. The joule is a larger unit of energy than the erg. By definition one joule = 1×10^7 ergs.

DIMENSIONAL ANALYSIS

Quantity	Equivalent	c. g. s. Unit	Fundamental Unit	Definitions
length		centimeter	l	
mass		gram	m	
time		second	t	
average velocity	$\frac{\text{distance}}{\text{time}}$	$\frac{\text{cm}}{\text{sec}} = \text{cm sec}^{-1}$	lt ⁻¹	Distance covered per unit of time
acceleration	$\frac{\text{distance}}{\text{time}^2}$	$\frac{\text{cm}}{\text{sec}^2} = \text{cm sec}^{-2}$	lt ⁻²	Change of velocity per unit of time
force	mass x acceleration due to gravity	$\frac{\text{g cm}}{\text{sec}^2} = \text{g cm sec}^{-2} = \text{dyne}$	mlt ⁻²	One dyne will accelerate 1 gram of mass 1 cm per second
energy				
work	force x distance	$\frac{\text{g cm}}{\text{sec}^2} \times \text{cm} = \text{g cm sec}^{-2}$	ml ² t ⁻²	One erg is 1 dyne acting thru 1 cm. One joule is 1 x 10 ⁷ ergs.
potential energy	force x distance	$\frac{\text{g cm}}{\text{sec}^2} \times \text{cm} = \text{g cm}^2 \text{sec}^{-2}$	ml ² t ⁻²	One calorie is 4.18 joules or 4.18 x 10 ⁷ ergs.
kinetic energy	$\frac{1}{2} \text{mass} \times \text{velocity}^2$	$\text{g} \times \left(\frac{\text{cm}}{\text{sec}}\right)^2 = \text{g cm}^2 \text{sec}^{-2}$	ml ² t ⁻²	
mass energy (Einstein equation)	mass x (velocity of light) ²	$\text{g} \left(\frac{\text{cm}}{\text{sec}}\right)^2 = \text{g cm}^2 \text{sec}^{-2}$	ml ² t ⁻²	One electron volt is 1.6 x 10 ⁻¹² ergs.
momentum	mass x velocity	$\frac{\text{g cm}}{\text{sec}} = \text{g cm sec}^{-1}$	mlt ⁻¹	
	force x time	$\frac{\text{g cm}}{\text{sec}^2} \times \text{sec} = \text{g cm sec}^{-1}$	mlt ⁻¹	
action	work x time	$\frac{\text{g cm}}{\text{sec}^2} \times \text{cm} \times \text{sec} = \text{g cm}^2 \text{sec}^{-1}$	ml ² t ⁻¹	
power	$\frac{\text{work}}{\text{time}}$	$\text{g cm}^2/\text{sec}^2/\text{sec}$	ml ² t ⁻³	

Resource Sheet 2¹

OBSERVATION, "BLACK BOXES," AND THE SCIENTIFIC MODEL

Write a description of the contents of the taped box assigned to you. Obtain as much information as you can about the contents of the box by tilting the box or by shaking it gently, but do not open the box. As you proceed with the investigation of the contents of the box, make appropriate entries of your findings in your notebook.

Questions

1. Provide a hypothetical model suggesting what is contained in the box, which is consistent with some of your observations and inconsistent with other of your observations. What can you say about the truth and value of this hypothesis?
2. Provide a hypothesis which is consistent with some of your observations and untested by other observations. Evaluate this hypothesis.
3. Provide a hypothesis which is tested by and consistent with all your observations. Evaluate this hypothesis.
4. In what way is the above sequence of exercises similar to the development of the present day concept of the atom? Upon what kind of evidence are theories about the atom based? Will anyone ever see a single atom?
5. What is the relationship between a hypothesis and a scientific model?

¹ Reproduced by permission from Chemistry Laboratory, Volume 1, Second Trial Edition, page 10, prepared by the Chemical Bond Approach Committee.

Resource Sheet 3

FUNDAMENTAL FORCES

A physical system can be analyzed in terms of three fundamental forces: gravitational, electromagnetic, and nuclear. Of these the third is probably the least understood and may be a composite of the other two. Classical mechanics and electrostatics provide adequate descriptions of many macroscopic phenomena and the inverse square relationships expressed by the law of universal gravitation and Coulomb's law are extremely useful. For events at distances within and among atoms and for speeds approaching the velocity of light(c) as well as for electromagnetic radiations, quantum mechanical interpretation becomes necessary.

The introduction of the electromagnetic spectrum requires examination of the wave-particle duality and the law of photochemical equivalence as well as the relationship of the speed of electromagnetic radiations (c), their wave length (λ), frequency (ν), and energy ($h\nu$ or Planck's constant $\times$ frequency). The following equations are useful in making these connections:

$$c = \lambda \nu$$

$$E = h \nu$$

The fact that gravitational and electromagnetic forces are not yet related by a unifying equation should be introduced with high ability students whose study of dimensional analysis might lead them to expect such a relationship to be possible.

Resource Sheet 4

QUANTUM MECHANICS

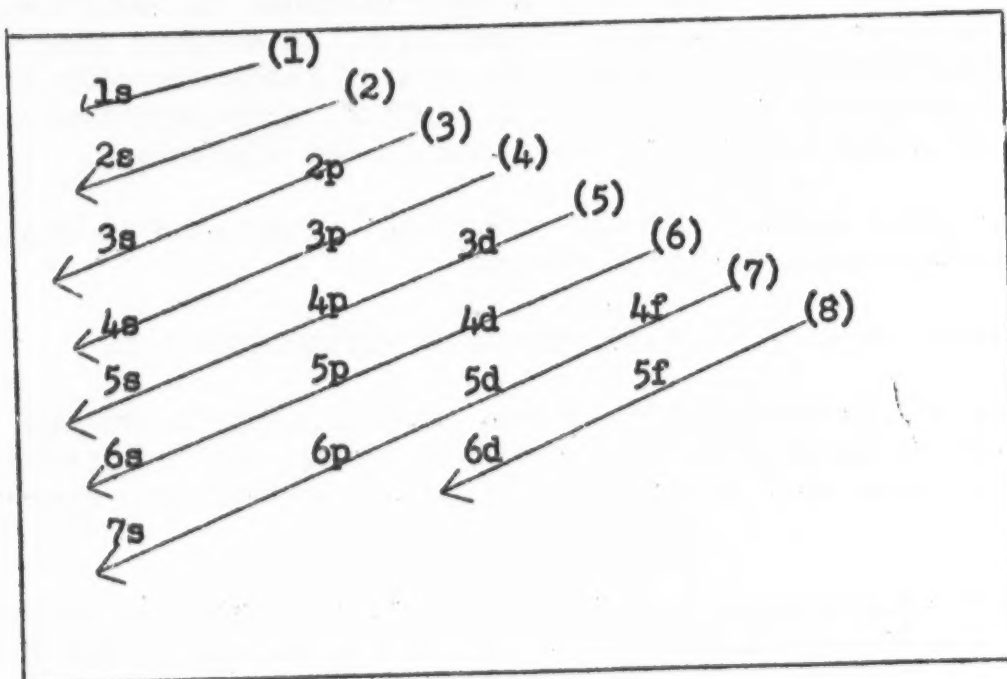
The wave-particle treatment of the electron seeks to relate mathematically the energy, spin, momentum, behavior in a magnetic field, and other characteristics of the electron to the probability of finding the electron at any distance from the nucleus. In an effort to explain why atoms do not collapse ordinary laws of motion are replaced with an equation representing probabilities. The modern wave theory was developed from a study of the hydrogen atom but has been extended to describe the properties of the other elements and, in addition, to explain chemical bonding. This detailed study of atomic structures leads directly to a periodic classification of the elements, a tool of major importance for systematizing and understanding the reactions of the elements.

The following basic ideas or 'ground rules' must be adopted in dealing with electron configuration in these terms:

1. The electron has both wave and particle characteristics.
2. The energy of electrons in atoms has certain specific values; that is, it is quantized. Electrons in moving from one energy level to another emit or absorb photons having definite energy values.
3. The electron population in a principal quantum level is limited to $2n^2$. The principal quantum number is designated by the letter n .
4. Each principal quantum level consists of one or more energy sublevels. The number of these sublevels in any main shell is equal to the value of n . These sublevels are referred to by the azimuthal quantum number l .
5. The order of occupancy of energy levels follows certain rules:
 - a. Pauli's Exclusion Principle
 - b. Hund's rule
 - c. Penetration or overlapping of subshells

The following device is an aid to memory in predicting order of occupancy and is read by following the arrows in the indicated numerical order.

ORDER OF OCCUPANCY



Resource Sheet 5¹

QUANTUM LEVEL DIAGRAM SHOWING MAINSHELLS

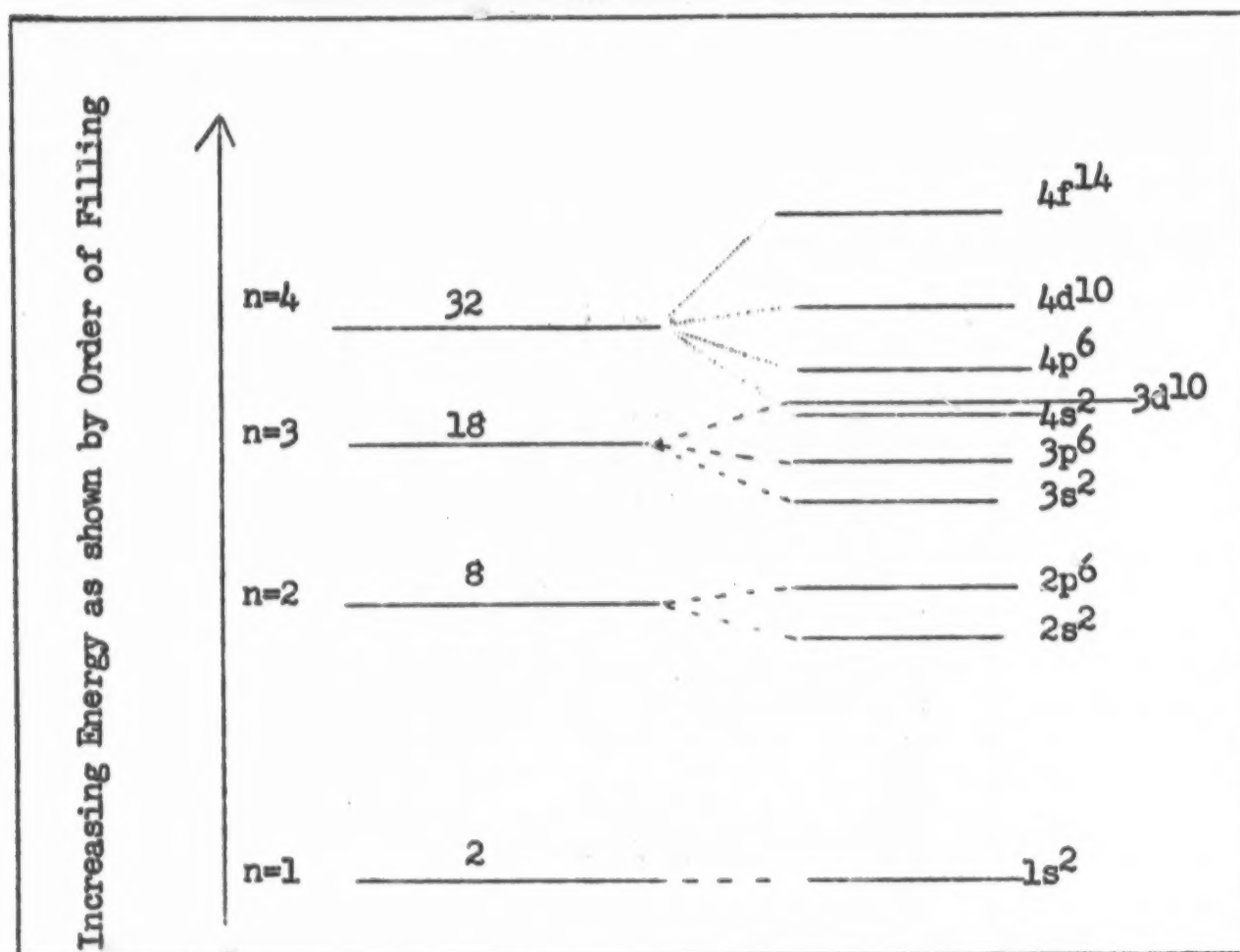
↑ INCREASING ENERGY	Q	$2n^2 = 2(7)^2 = 98$	n=7
	P	$2n^2 = 2(6)^2 = 72$	n=6
	O	$2n^2 = 2(5)^2 = 50$	n=5
	N	$2n^2 = 2(4)^2 = 32$	n=4
	M	$2n^2 = 2(3)^2 = 18$	n=3
	L	$2n^2 = 2(2)^2 = 8$	n=2
	K	$2n^2 = 2(1)^2 = 2$	n=1

Electron in the lowest energy level (n=1) are referred to as being in the K or innermost shell. These are the most tightly bound electrons. The probability of finding electrons between quantum levels is small.

¹Adapted from Sienko and Plane, Chemistry, p. 51

Resource Sheet 6¹

ENERGY LEVEL DIAGRAM SHOWING SUBSHELLS



¹Adapted from Sienko and Plane, Chemistry, p. 56

Resource Sheet 7

ENERGY LEVEL BOARD

A simple but effective aid for teaching electron configuration is diagrammed on the next page. It can be constructed from easily obtained materials. A series of colored bands painted on peg board indicate the quantum levels. Orbitals are represented by tool holders designed to support small screw drivers. Red and blue marbles represent electrons, the two colors being used in order to show opposite spins. The principal quantum level is painted a distinctive color. The energy levels are numbered and lettered at the left and the order of filling of orbitals is given in the lower right hand corner. It must be remembered, however, that this teaching device, like all other aids, tends to oversimplify complex ideas.

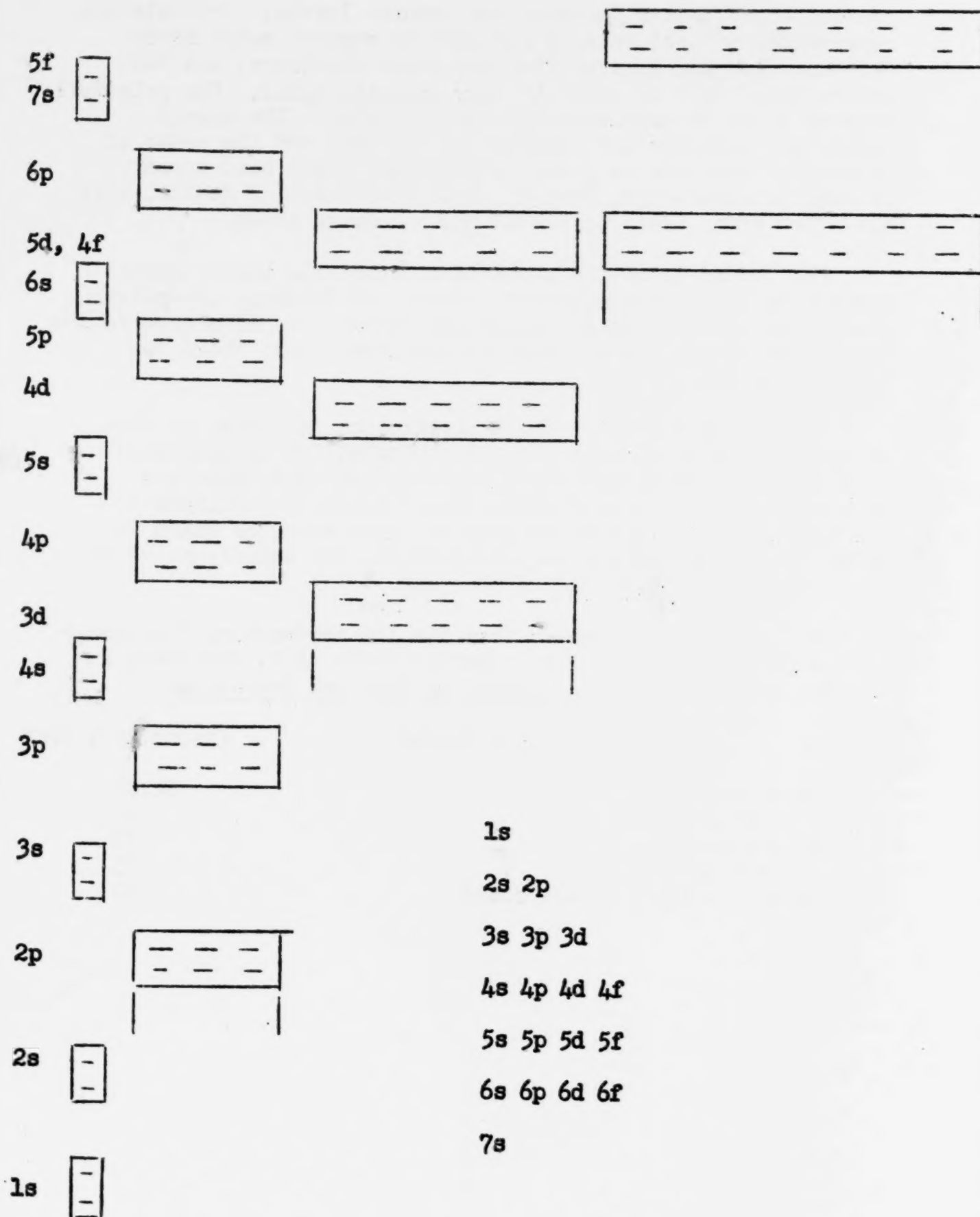
The build-up of the atoms of successively higher atomic numbers is easily accomplished. Order of filling, non-pairing ground and excited states, quantized energy, and line spectra are only a few of the "hard-to-get-across-ideas" this board can help to clarify.

The use of a 3' x 4' board permits the inclusion of five principal levels, through the "f" orbitals. It is suggested that the board be framed for durability and appearance and braced so that it is self-supporting. Taping the holders to the back will aid in keeping them in place when the board is moved. It is worthwhile to construct the aid solidly since it can be used many times during the year.

This device was adapted from "An Aid to Teaching Electronic Configurations of Atoms," as reported by Dr. R.T. Sanderson in the May 1960 issue of the Journal of Chemical Education.

Materials Needed	Approximate Cost
1 piece of pegboard, 3' x 4'	\$2.00
1 1/2 feet of 2" molding	1.50
3 dozen red marbles	.75
3 dozen blue marbles	.75
5 dozen tool holders (small size)	5.00

ENERGY LEVELS



STOCK NOMENCLATURE OF COMPOUNDS

Although many chemical compounds have trivial names, some of which have been used for hundreds of years, most substances are named by chemists in one of two ways - by the classical system or by the Stock system. In the old classical system, which is still in use, names of compounds are devised by adding various prefixes and suffixes to the names of certain elements in the compounds. For example, in the classical system, the compound with the formula FeO is called ferrous oxide. Here the suffix "ous" is added to the root of the Latin word meaning "iron." Another oxide of iron, Fe_2O_3 (trivial name: hematite), is called ferric oxide in the classical system.

To provide names which would better indicate the formulas of compounds, the Stock system was recommended in 1940¹⁾ by the International Union of Pure and Applied Chemistry. In this system, which is now used by many chemists, Roman numerals replace some of the prefixes and suffixes. Thus, in the Stock system, FeO is called iron (II) oxide, and Fe_2O_3 is called iron (III) oxide. The Roman numerals in these names indicate the oxidation state of the iron in a less ambiguous way than do the suffixes ous and ic in the old classical names.

Some examples of compounds named by the old system and by the new Stock system are listed in Table B-1.

In 1940 the Stock nomenclature was recommended for binary (two element) compounds of metals with non-metals. It has recently been suggested²⁾ that the Stock system be extended and used to name the compounds of non-metals with other non-metals. The compounds listed in Table B-2 are named by the old system and by the new Stock system.

A method for naming complex ions was suggested by Werner, and its modification to include Roman numerals to indicate the oxidation state of the metal is known as the Stock-Werner system. This system was included in the 1940 recommendations.¹⁾ To construct the name of a complex anion which contains a metal atom as the central atom, the first step is to indicate the number of atoms or groups of atoms coordinated with the metal by using a prefix (mono, di, tri, tetra, etc.). Next, the coordinating groups are given names ending in "-o" (NO_2^- , nitro; Cl^- , chloro; CN^- , cyano; H_2O , aquo; etc.)³⁾ Finally, the metal is named, and in an anion,

* Reproduced by permission from Chemistry, Volume I, Second Edition Pages A-255 to A-258 prepared by the Chemical Bond Approach Committee.

- 1) Jorissen, W.P.; Bassett, H.; Damiens, A.; Fichter, F.; and Rémy, H., J. Am. Chem. Soc., **63**, 889 (1941).
- 2) Brasted, Robert C., J. Chem. Ed., **35**, 136 (1958). Reprinted in CBA Supplementary Readings, page 48.
- 3) An exception is NH_3 which is called "ammine" in complex ions.

is given the suffix "ate," and the oxidation number is indicated by a Roman numeral. For example, the ion, $\text{Fe}(\text{CN})_6$ is called hexacyanoferrate (II) ion. Some examples of complex anions with their old names and their Stock-Werner names are given in Table B-3.

TABLE B-1

Formulas and Names of Some Compounds of Metals with Non-Metals

<u>Formula</u>	<u>Old Name</u>	<u>Stock Name</u>
CuCl_2	Cupric chloride	Copper (II) chloride
Cu_2O_3	Copper trioxide	Copper (III) oxide
CuO	Cupric oxide	Copper (II) oxide
Fe_3O_4	Triiron tetroxide (magnetic oxide of iron)	Iron (II,III) oxide
Pb_3O_4	Lead tetroxide	Lead (II,II,IV) oxide
MnCl_2	Manganous chloride	Manganese (II) chloride
MnCl_3	Manganic chloride	Manganese (III) chloride
Mn_2O_5	Manganese pentoxide	Manganese (V) oxide
Mn_2O_7	Manganese heptoxide	Manganese (VII) oxide

TABLE B-2

Formulas and Names of Some Compounds of Non-metals with Non-metals

<u>Formula</u>	<u>Old Name</u>	<u>Stock Name</u>
N_2O	nitrous oxide	nitrogen (I) oxide
NO	nitric oxide	nitrogen (II) oxide
NO_2	nitrogen dioxide	nitrogen (IV) oxide
N_2O_4	nitrogen tetroxide	dimer of nitrogen (IV) oxide
N_2O_5	nitrogen pentoxide	nitrogen (V) oxide
Cl_2O	chlorine monoxide	chlorine (I) oxide
ClO_2	chlorine dioxide	chlorine (IV) oxide

TABLE B-3

Formulas and Names of Some Complex Anions

<u>Formula</u>	<u>Old Name</u>	<u>Stock-Werner Name</u>
$\text{Fe}(\text{CN})_6^{=}$	ferricyanide ion	hexacyanoferrate (III) ion
$\text{Fe}(\text{CN})_6^{-}$	ferrocyanide ion	hexacyanoferrate (II) ion
$\text{PtCl}_6^{=}$	chloroplatinite ion	hexachloroplatinate (II) ion
$\text{Au}(\text{CN})_2^{-}$	cyanoaurite ion	dicyanoaurate (I) ion
$\text{Zn}(\text{OH})_4^{=}$	zincate ion	tetrahydroxozincate (II) ion

Complex cations are named by first using the prefix to indicate the number of complexing groups, second by naming the complexing group or groups, and then by adding the name of the metal without a suffix. Examples are given in Table B-4.

TABLE B-4

Formulas and Names of Some Complex Cations

<u>Formula</u>	<u>Old Name</u>	<u>Stock-Werner Name</u>
$\text{Cu}(\text{H}_2\text{O})_4^{++}$	tetrahydrocupric ion	tetraquocopper (II) ion
$\text{Ag}(\text{NH}_3)_2^{+}$	silver ammonia complex ion	diamminesilver (I) ion

It has been suggested ²⁾ that the Stock-Werner system of nomenclature be extended to oxyanions. In this system the names of all oxyanions would end in ate, and the oxidation state of the central atom would be indicated by a Roman numeral. Some oxyanions and their suggested names are given in Table B-5.

TABLE B-5

Suggested Names for Some Oxyanions

<u>Formula</u>	<u>Old Name</u>	<u>Suggested Stock Name</u>
NO_2^{-}	nitrite ion	nitrate (II) ion
NO_3^{-}	nitrate ion	nitrate (V) ion
$\text{SO}_2^{=}$	sulfoxylate ion	sulfate (II) ion
$\text{SO}_3^{=}$	sulfite ion	sulfate (IV) ion
$\text{SO}_4^{=}$	sulfate ion	sulfate (VI) ion

New Prefixes ¹

10^{12} - tera T

10^9 - giga G

10^6 - mega M

10^3 - kilo k

10^2 - hecto h

10 - deka dk

10^{-1} - deci d

10^{-2} - centi c

10^{-3} - milli m

10^{-6} - micro u

10^{-9} - nano n

10^{-12} - pico p

¹ Reproduced with permission from the Journal of Chemical Education, Volume 37, Number 2, page 85.

SUGGESTIONS FOR INDEPENDENT STUDY

1. Study and write a report on degree of uncertainty in experimental results and calculations. See DeRose, Principles of Measurement, and other references.
2. Design and build a vernier for use in making fine measurements in the laboratory.
3. Using data obtained in the laboratory, prepare a graph showing the density of liquid water as a function of its temperature over a range from 0°C. to 100°C.
4. Read and summarize a philosophical or historical discussion concerning science, such as A. N. Whitehead's Science and the Modern World, or James Conant's On Understanding Science. Refer to the bibliography for other books.
5. Study an elementary introduction to probability, such as Introductory Probability and Statistical Inference for Secondary Schools, chapters 4 and 5. Work representative problems and explain selected ones to the class.
6. Determine the mass of an electron. See PSSC Laboratory Guide for Physics for some suggestions.
7. Determine the maximum thickness of an oil molecule, as suggested in the PSSC Laboratory Guide for Physics, page 13.
8. Build a wave machine. For instructions see Similarities in Wave Behavior by John N. Shive, obtainable from the Williams and Wilkins Company, 428 East Preston Street, Baltimore 2, Maryland, for 35¢.
9. Read an advanced text to find out why it is believed that the electron configuration of an oxygen molecule is $:O::O:$ rather than $O::O$.
10. Read and report on the work of Moseley, referring to the original accounts.
11. Verify Coulomb's law. See the PSSC Laboratory Guide for Physics and other references for suggestions.
12. Determine the true formula of tin (IV) oxide by oxidation with nitric acid using the rule of Dulong and Petit. Use tin foil rather than granular tin.
13. Determine Avogadro's number by some experimental method, such as suggested in the extension of experiment 3, Scientific Experiments in Chemistry, Teacher's Book.
14. Study the essential relationships between equivalent weight and specific heat, and between atomic weight and specific heat, as suggested in Science and Math Weekly, January 25, 1961, page 34.
15. Verify a weight-weight or weight-volume problem as accurately as possible and account for any errors in the data.
16. Verify the law of multiple proportions, possibly as described in Sienko and Plane, Experimental Chemistry, "Multiple Proportions."
17. Devise an experiment to show what percentage of the air must be oxygen to support the combustion of wood.

UNIT TWO

PERIODIC RELATIONSHIPS

I. Scope of the Unit

Periodicity of chemical properties is the principal concept of Unit Two and should be introduced by discussing the historical antecedents of the present systems of classification. The central importance of periodic relationships as predictive and integrative devices should become clear as trends in properties within periods, groups, and families are studied.

Although all families of elements show property trends it is suggested that the inert gases be introduced first as examples of the configurational stability which other elements approach by transferring or sharing electrons in chemical reaction. The halogens are introduced because they provide examples of all three physical states within a single family and because these elements lend themselves to numerous experiments and demonstrations.

After the entire class has studied the inert gases and the halogens, students will have an idea of how to approach the study of other elements. The class may then be divided into smaller groups of students who will investigate and report on other periods and groups. Such properties as boiling points, melting points, atomic radii, ionic radii, ionization potentials, and electronegativity should be emphasized.

The unit may be concluded by relating the foregoing information to electron configuration and by having students predict the properties of a group of elements not heretofore studied. They should be aware of the fact that although the idea of periodicity was originally empirically grounded, it is at present supported by our understanding of electron configuration and is subject to mathematical expression in quantum mechanics.

Periodic Relationships

I. Development of the concept of periodicity

A. Historical background

B. Forms of the table

1. Short
2. Long
3. Special

C. Groupings of elements

II. Selected periods, groups, and families

A. Inert gases

1. Structure and properties
2. Uses

B. Halogens

1. Individual properties and preparation

- a. Fluorine
- b. Chlorine
- c. Bromine
- d. Iodine

2. Structural relationships and group properties
3. Compounds and reactions

C. IA, IIA, VIA, IB, IIIB, the lanthanides, and the actinides

D. Periods three and four

E. Prediction of properties by chart position

III. Electron configuration and trends

A. Atomic radii

B. Ionic radii

C. Ionization potential and electron affinity

D. Electronegativity

E. Combining tendencies

CONTENT	TEACHING SUGGESTIONS	REFERENCES																		
I. Development of the concept of periodicity A. Historical background	The styrofoam model devised by Sanderson will be of great value in teaching this unit. It is suggested that the model be constructed before topic I is completed. Ask the students to recall the major divisions of biology and to suggest reasons why classification is necessary. What are the methods for the classification of the physical states of matter? What are the areas or divisions of mathematics? Use the above questions as a basis for a discussion to show that the chemist has been able to organize his work with the use of a periodic chart. Introduce and point out the limitations of the early attempts at classification. Include a discussion of the system of classification used by the Greek philosophers and that of the medieval alchemists. Have students read to find out how the periodic chart has been developed. Discuss the evolution of the ideas for organizing the elements into a logical arrangement on the basis of their properties. Ask each student to summarize the information in a chart such as the one below: DEVELOPMENT OF THE PERIODIC TABLE <table border="1" data-bbox="1248 602 1561 1673"> <thead> <tr> <th>Scientists</th><th>Dates</th><th>Contribution</th></tr> </thead> <tbody> <tr> <td>Dobereiner</td><td></td><td></td></tr> <tr> <td>Newlands</td><td></td><td></td></tr> <tr> <td>Meyer</td><td></td><td></td></tr> <tr> <td>Mendeleev</td><td></td><td></td></tr> <tr> <td>Moseley</td><td></td><td></td></tr> </tbody> </table>	Scientists	Dates	Contribution	Dobereiner			Newlands			Meyer			Mendeleev			Moseley			Sanderson <u>Principles and Construction of New Chemistry Teaching Aids</u> pp. 1-13 Young and Petty <u>Chemistry for Progress</u> pp. 1-6 Dull, et al. <u>Modern Chemistry</u> pp. 55-60 Markham and Smith <u>General Chemistry</u> pp. 151-156 Garrett, et al. <u>Chemistry</u> pp. 116-121
Scientists	Dates	Contribution																		
Dobereiner																				
Newlands																				
Meyer																				
Mendeleev																				
Moseley																				

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Forms of the table 1. Short 2. Long 3. Special	Play the recording on the life of Mendeleev. Ask the students to state relationships which enabled Mendeleev to develop his form of the chart. What effect did public opinion have? Refer the students to a short-form wall chart and discuss its uses and limitations. Under limitations include the placement of two families in several groups and the illogical placement of Group VIII. Point out the chart's value in organizing the elements according to electron structure and properties. Display the extended form of the periodic table. Point out how this chart eliminates the awkward arrangement of families found in the short form. Ask the students to locate the elements in Group VIII and suggest why this placement is logical. Show how the arrangement of the elements depends on electron configuration. Ask several students to investigate and report on other forms of the periodic chart including three-dimensional charts, some of which might be constructed by the students.	Bradbury, et al. <u>Chemistry and You</u> pp. 319-322 Seaborg and Valenes <u>Elements of the Universe</u> pp. 62-68 Westinghouse Recording "The Missing Element" Garrett, et al <u>Op. cit.</u> pp. 118-120 Dull, et al. <u>Op. cit.</u> pp. 56-57 Garrett, et al. <u>Op. cit.</u> pp. 121-124 Dull, et al. <u>Op. cit.</u> pp. 58-63 Life Filmstrip "The Atom"

CONTENT	TEACHING SUGGESTIONS	REFERENCES
C. Groupings of elements II. Selected periods, groups, and families A. Inert gases	Point out the major groupings on a periodic chart. Teach students to distinguish among the terms period, group, and family. Refer to Resource Sheets 1A, 1B, and 1C. These sheets are to be completed by each student for each family or group studied in this unit. The sheets should be filled in by the students as they study the family in question and used later as a source of information for the culminating activities in topic III. Give each student a copy of Resource Sheets 1A, 1B, and 1C. Inform the students that they are to complete these charts for the inert gases filling in the properties as they are encountered in reading, class discussions, and student reports.	Kieffer <u>Supplementary Readings for Chemical Bond Approach</u> <u>pp. 11-13, 41-42</u> <u>Journal of Chemical Education</u> Vol. 33, No. 10, p. 492 <u>The Science Teacher</u> Vol. 26, No. 2 pp. 96-101 Resource Sheets 1A, 1B, 1C Resource Sheets 1A, 1B, 1C

CONTENT	TEACHING SUGGESTIONS	REFERENCES
1. Structure and properties	Note: In Resource Sheet 1 C, the specific gravity of all gases is calculated with air as the standard; for liquids and solids, the specific gravity is based on water. Review the electron configuration of the inert gases. Ask the students to predict the electron structure of the inert gas beyond radon. Have several students explain the reasoning used to arrive at this electron configuration. Ask several students to prepare reports on each of the inert gases. Include the discovery and properties of the gases. After the reports, pose this question: Why are the gases of family eight said to be inert? *Investigate the relationship of boiling point and electron structure in reference to van der Waals forces for the inert gases. Students should study the crystalline structure or the inert gases and explain why they have cubical structures.	Dull, et al. Op. cit. p. 407 Markham and Smith Op. cit. pp. 169-170 Garrett, et al. Op. cit. pp. 175-179 Dull, et al. Op. cit. pp. 406-408 Markham and Smith Op. cit. pp. 290-294 Davis <u>The Chemical Elements</u> pp. 142-150 Markham and Smith Op. cit. pp. 292-293

CONTENT	TEACHING SUGGESTIONS	REFERENCES
Ask the students to explain why the structure of helium differs from that of the other inert gases. *Have a student look up the meaning of heat of vaporization and explain why the heats of vaporization of the inert gases become larger as their boiling points rise. Give each student two copies of Resource Sheet 1B. Have one entitled "Atomic Radii" and the other "Ionization Potential." From the information given in Resource Sheet 1C, ask students to draw circles to scale to represent the values of the properties listed above. Have them explain the variation in atomic radii and ionization potential by relating these properties to the electron configuration of the inert gases. Explain the terms ionic radii and electronegativity. Pose the question "Why are no values given for the ionic radii or electronegativity for the inert gases?" Recall the discussion of bonding in Unit One. Point out that atoms approach inert gas electron configuration by forming compounds. The element chlorine which precedes the inert gas argon, and potassium which follows it can be used for illustrative purposes. For additional discussion include fluorine and sodium. Have a student report on the uses of the inert gases, including a demonstration in which a current is passed through several tubes containing different inert gases. Students should 2. Uses	Welch "Periodic Chart of the Atoms" Sienko and Plane Chemistry pp. 151-153 Sanderson Chemical Periodicity pp. 70-71 Resource Sheet 1B Resource Sheet 1C Sienko and Plane Op. cit. pp. 86-88, 371 Garrett, et al. Op. cit. pp. 175-179	

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Halogens 1. Individual properties and preparation a. Fluorine b. Chlorine	be asked to offer explanations for the behavior of the gases in the tubes. Give each student another copy of Resource Sheet 1A, completed during the study of the halogens. The properties of the halogens can be entered as they are encountered in the reading assignments, the demonstrations, and the class discussions. Note: The halogens produce bad "burns" which heal slowly. Chlorine vapor causes a lung inflammation. Exercise special care in handling these elements. Since free fluoroine is difficult to prepare and dangerous to handle, teach the properties and preparation of fluorine through discussion and reading assignments. Demonstrate the preparation of chlorine. Stress first the physical properties that can be observed from the demonstration. Then introduce the chemical properties of chlorine by demonstrating various reactions of chlorine gas.	Markham and Smith <u>Op. cit.</u> pp. 293-294 Resource Sheet 1A Dull, et al. <u>Op. cit.</u> pp. 359-261 Garrett, et al. <u>Op. cit.</u> pp. 314-317 Markham and Reilley <u>A Laboratory Manual For General Chemistry</u> pp. 235-239

CONTENT	TEACHING SUGGESTIONS	REFERENCES
c. Bromine	Discuss the reasons for the chemical properties observed and have students write equations for all the reactions which occur. Ask students to complete Chart 1A for chlorine by reading from texts and references. Demonstrate the preparation of bromine and discuss the properties that can be observed from the experiment. Have students write equations for the reactions and compare the properties to those of chlorine, suggesting reasons for the similarities and differences observed. Ask students to read about those properties of bromine not learned from the demonstration and add them to their chart.	Dull, et al. <u>Laboratory Experiments in Chemistry</u> pp. 93-94 Dull, et al. <u>Op. cit. (text)</u> pp. 361-366 Garrett, et al. <u>Op. cit.</u> pp. 317-321 Bradbury, et al. <u>Op. cit.</u> pp. 291-301 Markham and Reilley <u>Op. cit.</u> pp. 235-239 Dull, et al. <u>Op. cit. (manual)</u> pp. 97-98 Garrett, et al. <u>Op. cit.</u> pp. 321-322 Dull, et al. <u>Op. cit. (text)</u> pp. 368-370

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	Recall the material on electron configuration discussed in Unit One. Discuss the similarities and differences in the halogen electron structure. Refer to Resource Sheet 1B used to show the variation of the atomic radii of the inert gases. The students should examine Resource Sheet 1C and determine a scale for illustrating the atomic radii as circles of different sizes. Have the students complete Chart 1B for the halogens. Discuss the trend in the size of the atomic radii in relation to the electron structure of the halogens. Use a blank form of Resource Sheet 1B. Have the students determine the scale to be used to represent the ionic radii of the halogens. Refer to Resource Sheet 1C for values. Ask the students to use electron configuration to explain the difference in the size of the halogen atoms and ions. Which of the inert gases do the chloride and bromide ions resemble in electron configuration? Refer the students to Resource Sheet 1B on which they have recorded the ionization potentials of the inert gases. Proceed in the same manner as directed under ionic radii and represent the ionization potentials of the halogens. Ask the students to explain the trend in ionization potential on the basis of electron configuration.	Sienko and Plane <u>Op. cit.</u> <u>p. 530</u> Garrett, et al. <u>Op. cit.</u> <u>p. 313</u> Resource Sheets 1B and 1C Resource Sheet 1C

CONTENTS	TEACHING SUGGESTIONS	REFERENCES
3. Compounds and reactions	Have students start a fresh chart using the form on Resource Sheet 1B. Proceed in the same way as directed under ionic radii and illustrate the electronegativity of the halogens. Discuss the trend in electronegativity. Ask the students to explain the trend. Discuss the formation of the halide salt, sodium chloride, illustrating the movement of the chlorine and sodium atoms toward lower energy states by assuming inert gas electron configuration. Have the students recall and discuss the bonding of ionic compounds and predict the formulas of other halide salts. Ask the students to perform a laboratory exercise on the identification of the halide ions. Have them report and explain the results of the addition of silver nitrate and then ammonium hydroxide to the halide salt solutions. They should write an equation for each reaction. *Have a student report on the halogen oxyacids. He should include the formulas for each series, the oxidation number of the halogen in each compound, the strength of each oxyacid as an oxidizing agent, their strength as an acid, and the uses of these acids.	Resource Sheet 1B Markham and Smith Op. cit. pp. 306-309 Markham and Reilley Op. cit. pp. 241-246 Bradbury, et al. Op. cit. pp. 317-318 Markham and Smith Op. cit. pp. 312-315 CHEM Study Chemistry, an Experimental Science Vol. III pp. 22 4 to 22 9

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	Recall the diatomic structure of the halogens. Have the students explain the formation of diatomic molecules by halogens. Pose these questions: 1. Would the bonds formed between atoms of the same halogen be polar or non-polar covalent? Between atoms of different halogens? 2. What types of forces would exist between the halogen molecules? 3. Are these forces strong or weak? 4. Would you expect the strength of the molecular forces to increase or decrease as the molecules get larger? Why? Have a student demonstrate the preparation and properties of hydrogen chloride gas. Ask the class to list the properties observed and to write an equation for the reaction. Ask the class to find out how hydrogen fluoride, hydrogen bromide, and hydrogen iodide can be prepared and write an equation for each preparation. The class should list and compare the properties of each of the hydrogen halides. Have the students investigate the relative reducing ability of each halide and make an activity series, arranging them from the most to the least active as reducing agents.	Sienko and Plane Op. cit. pp. 532-542 Dull, et al. Op. cit. (manual) pp. 95-96 Bradbury, et al. Op. cit. pp. 313-314 Dull, et al. Op. cit. (text) pp. 360-361, 364-367 372, 390

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	*Divide the class into three groups. Each group should prepare a different hydrogen halide from the appropriate salt following the procedure listed in Markham and Reilley. Have each group report its results and write equations to represent each reaction and the general equation for the formation of a halogen halide. Ask the students to make an activity table of the halide ions indicating their strength as reducing agents and to predict the position of the fluoride ion in this series. Discuss the significance of the halide reaction with sulfuric acid in relation to ion size, electron configuration, and redox potential. As a culminating activity for this topic, show the film, "Chlorine: A Representative Halogen." The students should consider the following during the discussion of the film: 1. Describe three properties which the halogens have in common. Give a reason or reasons why the halogens share these properties. 2. Predict the type of compound chlorine would form with francium. With carbon. 3. Make a reasonable prediction of the properties of astatine. What would the formula of its sodium salt be? Of its halogen acid?	Garrett, et al. Op. cit. pp. 325-327 Dull, et al. Op. cit. (manual) pp. 101-102 Markham and Reilley Op. cit. pp. 241-246 Markham and Smith Op. cit. pp. 310-312 County film #591.34 "Chlorine: A Representative Halogen"

CONTENT	TEACHING SUGGESTIONS	REFERENCES
C. Families IA, IIA, VIA, IB, IIIB, the lanthanides and actinides	Have student reports on the following topics: 1. The use of chlorine in bleaching 2. The use of fluorine in refrigeration (freons) 3. The use of bromine in gasoline (ethylene dibromide and octane rating) Under teacher direction the students have completed the study of two important families, the inert gases and the halogens. Definite characteristics and trends within these two families have been stressed and discussed. Divide the class into groups to study the following groups and families: IA, IIA, VIA, IB, IIIB, the lanthanide, and the actinide series. Other families might be added depending on teacher and student interest. The group plan of study should be similar to the one used for the halogens. Each group will be held responsible for collecting the data necessary to complete Resource Sheets IA and IB. Each student should be prepared to give an oral	Bradbury, et al. Op. cit. pp. 296-299 <u>Journal of Chemical Education</u> Vol. 32, No. 1 pp. 13-19 Dull, et al. Op. cit. (text) pp. 614-616 Bradbury, et al. Op. cit. pp. 486-487 Garrett, et al. Op. cit. pp. 294-311, 331-357, 569-584, 596-603, 633-667 Davis Op. cit. pp. 18-55, 65-112, 129-135, 153-161 Sienko and Plane Op. cit. (text) pp. 369-393, 435-463, 514-538

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	report which summarizes the family study. The report should include a discussion of the following topics: 1. The significance of the data collected to complete Resource Sheet 1A 2. The preparation and properties of the elements as based on laboratory work 3. The general reactions within the family 4. The trends of properties within the family 5. Uses To verify the properties of the elements, laboratory experiments should be selected from the following list: Forms of Sulfur. Dull, et al., pp. 103-104 Preparation and Properties of Hydrogen Sulfide. Dull, et al., pp. 105-106 Sulfur Dioxide and Sulfurous Acid. Dull, et al., pp. 107-108 Magnesium and Its Compounds. Dull, et al., pp. 127-128 Compounds of Copper. Dull, et al., pp. 137-138 Zinc and Its Compounds. Dull, et al., pp. 141-142 The Alkali Metals. The Copper Group. Alyea and Dutton, pp. 27-28 The Alkaline Earth Metals. The Zinc Group. Alyea and Dutton, pp. 29-30 Sulfur and Hydrogen Sulfide. Markham and Reilley, pp. 247-251 Sulfur Dioxide and Sulfurous Acid. Markham and Reilley, pp. 253-256	Bradbury, et al. Op. cit. pp. 249-282, 639-662 Young Practice in <u>Thinking</u> pp. 42-52, 55-56, 59-60

CONTENT	TEACHING SUGGESTIONS	REFERENCES
D. Periods three and four E. Predicting properties by chart position	Sulfur Trioxide and Sulfuric Acid. Markham and Reilley, pp. 257-261 The Chemistry of Sulfur. Joseph, et al., pp. 186-195 Tests for Various Metals. Joseph, et al., pp. 219-223 The Alkali Metals. Joseph, et al., pp. 223-227 Use period three to develop with the class the trends in atomic radii, ionic radii, ionization potential, electronegativity, the change from metallic to non-metallic character, and the formulas of the oxides for the elements within a period. Explain these trends in terms of electron configuration. *Have the high ability students trace and explain the trends of properties within period four. Use the board described in Resource Sheet 7, Unit One, to show why the transition elements have very similar properties. Instruct the students to complete a chart similar to the one below for each of the following sets of four elements: fluorine, chlorine, bromine and iodine; boron, aluminum, gallium, and indium; and oxygen, sulfur, selenium, and tellurium. Use the values from these charts to predict the same properties for astatine, thallium, and polonium respectively. Students should check their predicted values against the ones given in their texts or in a handbook.	Resource Sheet 1B Sanderson Op. cit. pp. 22, 26, 32 CHEM Study Op. cit. Vol. I pp. 7-18 to 7-22 Vol. III pp. 23-1 to 23-8 25-1 to 25-11, 25-20 to 25-40 Welch Chart "Periodic Chart of the Atoms" Markham and Reilley Op. cit. pp. 145-151 Hodgman (ed.) Handbook of Chemistry and Physics

CONTENT	TEACHING SUGGESTIONS	REFERENCES																				
	FAMILY TRENDS IN PROPERTIES <table><thead><tr><th>Element</th><th>Density</th><th>Melting Point</th><th>Metallic to Non-metallic Character</th></tr></thead><tbody><tr><td>Fluorine</td><td></td><td></td><td></td></tr><tr><td>Chlorine</td><td></td><td></td><td></td></tr><tr><td>Bromine</td><td></td><td></td><td></td></tr><tr><td>Iodine</td><td></td><td></td><td></td></tr></tbody></table> Ask the students to make a general statement concerning the trends in melting points, density, and metallic to non-metallic character within a family and to suggest reasons for these general tendencies. Properties of elements which have not been studied thoroughly can be predicted if the properties of the surrounding elements are known. Illustrate this concept by asking the students to look up the melting and boiling points of tin and tellurium, and to predict the values of these properties for antimony on the basis of its position in the chart and the values of the properties of the surrounding elements. Compare the predicted values with those given in a handbook. Predictions, using other sets of elements, should be made to reinforce this idea.	Element	Density	Melting Point	Metallic to Non-metallic Character	Fluorine				Chlorine				Bromine				Iodine				Hodgman (ed.) <u>Op. cit.</u> Resource Sheet 1C
Element	Density	Melting Point	Metallic to Non-metallic Character																			
Fluorine																						
Chlorine																						
Bromine																						
Iodine																						

CONTENT	TEACHING SUGGESTIONS	REFERENCES
III. Electron configuration and trends A. Atomic radii	For each of the following activities, refer to the set of resource sheets completed earlier in the unit. These periodic charts are valuable aids in relating property trends within families and groups to the electron configuration of the elements. Refer to the chart titled "Atomic Radii." Have the students write statements describing how the radii vary in each of the following situations: 1. Within a period, i.e. as s and p electrons are added to the outer-most energy level 2. Within a family, i.e. as n increases 3. Upon the completion of an outer-most level of eight electrons *4. Within a period of transition elements, i.e. as d electrons are added to the second outer-most energy level *5. Within a family of transition elements, i.e. as n increases 6. As s electrons are added to the outer-most shell above an inert element	Resource Sheet IB Sanderson <u>Op. cit.</u> pp. 26-32 IB Welch Chart <u>Op. cit.</u> Welch <u>Relative Sizes of Atoms and Ions in the Periodic Table</u> Sienko and Plane <u>Op. cit.</u> pp. 66-69 Garrett, et al. <u>Chemistry</u> pp. 125-126

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Ionic radii	Use these statements as a starting point for a class discussion. Apply Coulomb's law as a partial explanation of the variations in the size of atomic radii. Ask the students to locate the position of the largest and smallest atoms in the table and to explain why the atoms of the alkali metals are so much larger than the atoms of the preceding inert gases. Refer students to the chart of ionic radii. Ask them to write statements describing how the radii vary in each of the following situations: 1. Within a period, i.e. as s and p electrons are added to or removed from the outermost shell of an atom 2. Within a family, i.e. as n increases 3. Within a family of transition elements, i.e. as n increases 4. Within a period of transition elements, i.e. as s,p, and d electrons are removed from the outermost and second outermost level	Sanderson Op. cit. p. 42 Resource Sheet 1B

CONTENTS	TEACHING SUGGESTIONS	REFERENCES
	Have the students locate the largest and smallest ions on the periodic chart and suggest reasons for their sizes. Make a comparison of the atomic and ionic radii of elements by discussing the following questions: 1. How does the radius of each atom in family one compare with the radius of its ion? 2. How do the ionic radii vary as n increases in family one? 3. Answer the first two questions for families two, six, and seven, listing the trends family by family. 4. What are the reasons why the radius of a positive ion is less than that of its parent atom? 5. Why is the radius of a negative ion greater in size than that of its parent atom? 6. Compare the radii of the following groups of particles that are isoelectronic: O^{2-}, F^{-}, Ne, Na^{+} and Mg^{2+}. *7. Select other isoelectronic particles and compare their radii. Are the trends in these groups similar to those of the elements discussed in the previous question? Have the students suggest why the chemical activity of isoelectronic particles differ.	Resource Sheet 2B Welch <u>Op. cit.</u> Markham and Smith <u>Op. cit.</u> (front end sheet) Sanderson <u>Op. cit.</u> pp. 26-27

CONTENT	TEACHING SUGGESTIONS	REFERENCES
C. Ionization potential	Refer to the chart which summarizes the trend in ionization potential. Discuss the following questions with the class: 1. How does the ionization potential vary within a family? Within a period? Upon the completion of a shell of eight electrons? In isoelectronic particles? 2. Where are the highest ionization potentials found in the table? The lowest? 3. Compare the high and low values with the radii of the atoms and ions. Are there any similar trends?	Resource Sheet 1B Sienko and Plane <u>Op. cit.</u> <u>pp. 69-71</u> Markham and Smith <u>Op. cit.</u> <u>pp. 178-181</u> Garrett, et al. <u>Op. cit.</u> <u>pp. 88-89, 128</u>
D. Electronegativity	Refer to the Resource Sheet 1B on which electronegativities have been given. Base a class discussion on the following questions: 1. How does the electronegativity of elements vary within a family? Within a period? Upon the completion of 8 electrons? Among isoelectronic particles? *2. Compare the chart of ionization potentials with the potentials for electrons other than the first and suggest reasons for the variation in these potentials. Have the students complete the following tables:	Resource Sheet 1B Sienko and Plane <u>Op. cit.</u> <u>pp. 86-89</u> Markham and Smith <u>Op. cit.</u> <u>pp. 181-182</u>
E. Combining tendencies		

CONTENT	TEACHING SUGGESTIONS	REFERENCES																																													
	TRENDS OF FORMULAS IN A FAMILY <table><thead><tr><th>Family IA</th><th>Oxides</th><th>Bromides</th></tr></thead><tbody><tr><td>Lithium</td><td></td><td></td></tr><tr><td>Sodium</td><td></td><td></td></tr><tr><td>Potassium</td><td></td><td></td></tr><tr><td>Rubidium</td><td></td><td></td></tr><tr><td>Cesium</td><td></td><td></td></tr><tr><td>Francium</td><td></td><td></td></tr></tbody></table> TRENDS OF FORMULAS IN A PERIOD <table><thead><tr><th>Compounds</th><th>Na</th><th>Mg</th><th>Al</th><th>Si</th><th>P</th><th>S</th><th>Cl</th></tr></thead><tbody><tr><td>Oxides</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Bromides</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr></tbody></table>	Family IA	Oxides	Bromides	Lithium			Sodium			Potassium			Rubidium			Cesium			Francium			Compounds	Na	Mg	Al	Si	P	S	Cl	Oxides								Bromides								Resource Sheet 1B Welch Chart <u>Op. cit.</u>
Family IA	Oxides	Bromides																																													
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CONTENTS	TEACHING SUGGESTIONS	REFERENCES
	Ask the students to compare the formulas in the tables and to make general statements concerning the following topics: 1. The trends of formulas in a family 2. The trends of formulas in a period Have the class relate family number to electron configuration and to the oxidation number or numbers of the elements. Use this concept to help the students to predict formulas for other combinations of elements. The activities which follow are designed to pull together all the facts and concepts the students have encountered so far in the unit and to show them the predictive value of the periodic chart. Allow the students to use only their circle charts and the Sanderson Model. Require them to predict, in writing, the following information for Si, group IV, period 3. 1. Electron configuration 2. Approximate electronegativity 3. Approximate ionization potential 4. Approximate atomic radius 5. Approximate ionic radius 6. Oxidation state 7. Physical state	

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	Have the students write the orbital electron configuration for silicon and examine the orbital vacancies in order to predict its metallic or non-metallic character. Students should predict the nature of the bonds between silicon and oxygen, silicon and bromine, and silicon and carbon and write the formulas for these compounds. Ask the students to name the most common oxygen acid of silicon and write its formula. *High ability students should predict additional properties including boiling point, melting point, and heat of vaporization. Require the students to work individually for twenty minutes. At the end of this time, have several students present their predictions and the reasoning behind them. A class discussion should develop. Then make the following assignment: Eichinger classified the elements under five main headings. What are they and what is his basis for this grouping? Try to classify the elements under other headings. What is the basis of your grouping? Which classification is more helpful to you? Why?	Eichinger <u>The Electron Chart</u> p. 10

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	Use this assignment to initiate a class discussion on how the periodic chart contributes to the understanding of chemistry. Stress the need for such a classification. Have the students state the periodic law in their own words. Test the students' understanding of the use of the periodic chart to predict properties of elements. Assign each student an element from family five and ask him to predict its electron structure. On the basis of the electron configuration of the element, have him predict as many properties as he can. All students should trace the trends in atomic radii, ionic radii, ionization potential, electronegativity, and metallic to non-metallic character for the entire family. Have the students predict the trends in atomic radii, ionic radii, ionization potential, electronegativity, and change from metallic to non-metallic character for period two. Ask them to indicate the formulas of the chlorides of these elements. Finally, ask each student to state the periodic law as he now understands it. He should be able to formulate a fairly sophisticated statement such as the one given by Sanderson on page 13 of <u>Chemical Periodicity</u>, "The physical and chemical properties of the elements are a function of the electronic configuration of their atoms, which vary with increasing atomic number in a periodic manner." This entire activity can be used as a unit test.	

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of numerous alkali metals.

D. Audio visual aids

1. Film

Chlorine: A Representative Halogen (sound, 17 minutes.
Free, Central Film Library, Baltimore County Public
Schools, Towson Senior High School, Towson 4, Maryland)

Discusses the properties of chlorine and compares
chlorine's characteristics to those of the other
halogens.

2. Filmstrips

The Atom (55 frames, color, silent with captions. \$6.00,
Life Magazine and Society for Visual Education, Inc.,
100 East Ohio Street, Chicago 11, Illinois)

Discusses the historical background and structure
of the atom.

Relative Sizes of Atoms (29 frames, color, silent with
text. \$6.00, Encyclopedia Britannica Films, Inc.,
Wilmette, Illinois)

Illustrates the sizes of atoms by use of
styrofoam models.

3. Recording

The Missing Element: Adventures in Research (33 1/3
rpm, 15 minutes. \$10.00 set of 3 records, School Service
Department, Westinghouse Electric Corporation, Pittsburgh,
Pennsylvania)

4. Charts

Periodic Chart of the Atoms, No. 4854 (42x58. \$7.50, W.M.
Welch Scientific Company, Chicago 10, Illinois)

Periodic Table of the Elements, No. 12056 (62x52.
\$7.50, Central Scientific Company, Chicago 13, Illinois)

Relative Sizes of Atoms and Ions in the Periodic Table,
No. 4844 (42x58. \$5.00, W.M. Welch Scientific Company,
Chicago 10, Illinois)

Resource Sheet 1A

CLASSIFICATION OF FAMILY PROPERTIES

Property	E L E M E N T					
1. Atomic Number						
2. Atomic Weight						
3. Electron Configuration						
4. Atomic Radii						
5. Ionic Radii						
6. Ionization Potential						
7. Electro-negativity						
8. Physical State						
9. Color						
10. Melting Point						
11. Order of Activity (redox potential)						
12. Uses						

Resource Sheet 1B

THE PERIODIC CHART

[illegible]

Resource Sheet 1C
PROPERTIES OF ELEMENTS

Element		M.p.	B.p.	Sp. Gr.	I.P.	$r_{cov.}$	r_{ionic}
Aluminum	Al	659.7	2450	2.70	5.96	1.25	0.45
Antimony	Sb	630.5	1380	6.68	8.5	1.41	
Argon	Ar	-184	-181	1.40	15.76	1.91	
Arsenic (s)	As	874.5	610	5.73	10.5	1.21	
Barium	Ba	850	1537	3.59	5.22	1.98	1.29
Beryllium	Be	1280	1500	1.86	9.32	0.89	0.30
Bismuth	Bi	271	1560	9.80	8.0	1.52	1.16
Boron	B	2300	2550	3.33	8.28	0.80	0.20
Bromine	Br	-7.3	58.8	3.12	11.84	1.14	1.95 (-1)
Cadmium	Cd	320.9	767	8.64	8.99	1.41	0.92
Calcium	Ca	842	1240	1.55	6.12	1.74	0.94
Carbon	C	3500	4000	2.25g	11.25	0.77	
Cerium	Ce	815	1400	6.90	6.57	1.65	1.02 (+3)
Cesium	Cs	28.5	670	1.87	3.90	2.35	1.67
Chlorine	Cl	-102	-34.5	1.56	13.01	0.99	1.81
Chromium	Cr	1550	2475	7.20	6.77	1.17	0.55 (+3)
Cobalt	Co	1490	2900	8.70	7.84	1.16	0.78 (+2)
Copper	Cu	1083	2336	8.92	7.71	1.17	0.69 (+2)
Fluorine	F	-223	-187	1.11	17.42	0.72	1.33
Germanium	Ge	958.5	2700	5.35	8.13	1.22	
Gold	Au	1003	2600	19.3	9.22	1.34	1.15
Helium	He	-272	-269	0.126	24.58		
Hydrogen	H	-259	-253	0.07	13.60	0.28	1.54 (-1)
Iodine	I	114	183	4.93	10.44	1.33	2.19 (-1)
Iron	Fe	1535	2735	7.87	7.86	1.17	0.53 (+3)
Krypton	Kr	-157.2	-153.2	2.6	14.0	1.89	
Lead	Pb	327.4	1620	11.34	7.41	1.54	1.17 (+2)
Lithium	Li	186	1340	0.53	5.39	1.23	0.68
Magnesium	Mg	651	1107	1.74	7.64	1.36	0.65
Manganese	Mn	1260	1900	7.20	7.44	1.17	0.80 (+2)
Mercury	Hg	-38.9	356.6	13.6	10.42	1.44	1.05 (+2)
Molybdenum	Mo	2620	4000	10.22	7.38	1.29	0.68 (+4)
Neon	Ne	-249	-246	1.20	21.56	1.60	
Nickel	Ni	1452	2730	8.90	7.64	1.15	0.68
Niobium	Nb	1950	3300	8.57	6.77	1.34	0.70
Nitrogen	N	-210	-196	0.808	14.54	0.75	
Oxygen	O	-219	-183	1.14	13.61	0.74	1.45
Phosphorus (wh.)	P	44.1	280.5	1.82	11.0	1.10	
Platinum	Pt	1774	4130	21.45	8.88	1.26	0.52 (+2)
Potassium	K	62.3	760	0.86	4.35	2.03	1.33
Radium	Ra	960	1140	5	5.28		1.52
Radon	Rn	-71	-62	4.4	10.73		
Rubidium	Rb	38.5	700	1.53	4.19	2.16	1.48
Selenium	Se	217.4	685	4.80hx	9.75	1.17	2.02 (-2)
Silicon	Si	1414	2355	2.33	8.15	1.17	0.41
Silver	Ag	960.5	1950	10.5	7.57	1.34	1.13
Sodium	Na	97.5	880	0.97	5.15	1.57	0.98
Strontium	Sr	757	1366	2.6	5.70	1.91	1.10
Sulfur	S	119	444.6	2.06	10.36	1.04	1.90 (-2)
Tantalum	Ta	3030	5300	16.7	6	1.34	0.73
Tin	Sn	231.9	2260	5.75gr	7.33	1.40	0.74 (+4)
Titanium	Ti	1725	3000	4.43	6.84	1.32	0.64 (+4)
Tungsten	W	3370	5900	19.26	7.98	1.30	
Uranium	U	1133		18.7	4	1.42	0.89 (+4)
Vanadium	V	1710	3000	6.07	6.71	1.22	0.40 (+5)
Zinc	Zn	420	907	7.14	9.36	1.25	0.70
Zirconium	Zr	1860	3000	6.49	6.92	1.45	0.87

Resource Sheet 2

SUGGESTIONS FOR INDEPENDENT STUDY

1. Make a model of one of the three-dimensional forms of the periodic charts such as the spiral or helical.
2. One of the blanks on Mendeleev's chart was #85. Report to the class on the properties of this element. Explain why the element was not discovered in the natural state and give the details of its eventual discovery. Explore the discovery of elements #87 and #43.
3. Predict the properties of elements #104-#110 on the basis of their electron structure.
4. Prepare a report, complete with a bulletin board display, on one of the transition metals. Information on germanium, zirconium, plutonium, or hafnium is readily available. Show the electron arrangement of the element, the properties due to its structure, and the uses of the metal.
5. Prepare a bulletin board display on the various uses of the periodic chart.
6. Construct a working model of the apparatus used in the Frasch process for obtaining sulfur.
7. Compute the oxidation number of sulfur in each of the following substances: SO_2 , SO_3 , SO_4^{2-} , S_2 , S_8 , and H_2S .
What is the electron configuration in each case? Make Lewis dot diagrams to represent the structures. Relate the electron configuration of each substance to its properties.
8. Make a collection of sulfides by passing hydrogen sulfide gas through solutions of arsenic, lead, antimony, zinc, and cadmium salts. Filter and dry the solids. Display the precipitates in small vials.
9. Obtain a mixture of iodine and sand from your instructor. Decide upon a method to recover the iodine crystals. Attempt to make a one hundred per cent recovery.
10. Study models of the Nelson and Vorce cells described in industrial and college chemistry texts. Construct a working model. Explain and operate it for the class.
11. Prepare a labeled collection of the ores of as many metals as possible. Display and discuss the exhibit with your class.

12. Place some copper in each of the following solutions: concentrated sulfuric acid, dilute sulfuric acid, concentrated hydrochloric acid, dilute hydrochloric acid, concentrated nitric acid, moderately concentrated nitric acid, dilute nitric acid, concentrated ammonium hydroxide, and dilute ammonium hydroxide. Observe the reactions. Allow the reactions to stand overnight. Observe the reactions again. Write and explain the equation for each reaction. Explain why copper roofs and statues turn green.
13. Use actual specimens to make a chart showing the relative activity of metals. Place the active metals at the top and the less active metals at the bottom of the chart.
14. Devise and perform an experiment in which you determine the speed with which metals in sea water corrode. Use nickel, iron, copper, zinc, stainless steel, aluminum, and magnesium. Predict the speed of corrosion of each element on the basis of its electron configuration. Compare the predictions with the results. Explain any differences between predicted and experimental results.
15. Report on the use of silicon in transistors. Which of its properties makes silicon suitable for this use? What about silicon's electron configuration would indicate that it might possess properties necessary for use in a transistor?
16. Prepare a report on the formation of stalactites and stalagmites. Include a description of the chemical and physical processes that make these deposits possible.
17. Prepare some zinc sulfide by precipitation. Dry the compound and make a small quantity of paint using a suitable vehicle and dryer.
18. Prepare a report on the topic "Chemistry and Its Relation to Farming."
19. Prepare a report on "Abrasives, Their Manufacture and Importance."
20. Obtain from your teacher a solution containing group I and II cations. Analyze the solution according to the procedure given in any good qualitative analysis text. Become familiar with the procedure and the type of precipitate deposited by each cation so that identification becomes routine. Then obtain a solution containing an unknown number of cations from the same two groups. Analyze the unknown and report your results. On the completion of Unit Four return to this project and explain your results on the basis of solubility product.
21. Study the properties of iron, paying particular attention to its magnetic qualities. Investigate the relationship of iron's electron configuration and its magnetic character. On the basis of electron configuration predict other elements that might show magnetic properties. Read to confirm or disprove your predictions. Present your findings to the class in the form of a report. Supplement the report by charts and diagrams in which you compare the electron configuration and properties of the elements to those of iron.

MOTION AND DYNAMIC EQUILIBRIUM**I. Scope of the Unit**

The physical state of a system is most directly dependent on the fundamental and opposing forces of attraction and dispersion. The dispersive forces are a consequence of the kinetic energy or motion of the particles and increase in magnitude as heat or some other form of energy is applied to the system. The forces of attraction are more complex, probably consisting of dipole-dipole attractions, hydrogen bonds, van der Waals forces and, in some cases, primary bonds. Any system is in a state of dynamic equilibrium when these forces are equal and opposed.

The continuing dichotomy of enthalpy and entropy in physical systems is a parallel situation and its significance should be stressed since matter tends both toward a state of minimum enthalpy, i.e. internal energy and maximum entropy, i.e. disorder. Changes of state or within a state can be interpreted as opposition between enthalpy and entropy and between attractive and dispersive forces.

The maintenance or disturbance of equilibria between these forces is dependent on such factors as temperature, pressure, and volume although the effect of each of these factors varies from one state to another. Gases, liquids, and solids are considered from the point of view of dynamic equilibrium and the same general orientation is maintained in regard to solutions and colloidal dispersions.

In teaching this unit to regular classes it may be desirable to stress the attractive and dispersive forces and omit details of the enthalpy-entropy relationships. The decision concerning this matter should be made by the teacher who can estimate the ability of a given class and develop this unit at a suitable level.

Motion and Dynamic Dquilibrium

I. Fundamental concepts

- *A. Enthalpy and entropy
- B. Characteristics of a system in equilibrium
 - 1. Le Chatelier's principle
 - 2. Factors affecting equilibrium
- C. Kinetic-molecular theory
 - 1. Interacting forces
 - a. Energy and entropy
 - b. Forces of attraction and interparticle distance
 - c. Motion of particles and diffusion tendency
 - 2. Fundamental conditions
 - a. Temperature
 - b. Pressure
 - c. Volume

II. Special properties of gases

- A. Boyles's law
- B. Charles' law
- C. Combined laws
- D. Gay-Lussac's and Avogadro's laws
- E. Equation of state
- F. Dalton's law
- G. Graham's law

III. Special properties of liquids

- A. Surface tension
- B. Capillarity
- C. Viscosity

IV. Solids

- A. Amorphous solids
- B. Crystalline solids
 - 1. Methods of studying structure
 - 2. Fundamental parameters
 - a. Axial length
 - b. Crystal angles
 - 3. Crystallographic systems
 - 4. Forces determining structure

V. Changes of state

- A. Order of particles
- B. Energy relationships

1. Solid $\rightleftharpoons$ solid₂

- a. Transition point
- b. Heat of transition

2. Solid $\rightleftharpoons$ liquid

- a. Melting point and freezing point
- b. Heat of fusion
- c. Supercooling

3. Liquid $\rightleftharpoons$ gas

- a. Boiling point and condensation point
- b. Vapor pressure
- c. Heat of vaporization

4. Solid $\rightleftharpoons$ gas; sublimation

C. Equilibrium

- 1. Critical temperatures and pressures
- *2. Phase diagrams and triple point

VI. Solutions

A. Definitions

- 1. Solubility
- 2. Concentration

- a. General

- (1) Dilute and concentrated
 - (2) Unsaturated, saturated, and supersaturated

- b. Standardized

- (1) Molar
 - (2) Normal
 - (3) Formal
 - (4) Molal
 - (5) Per cent

B. Solution equilibrium

- 1. Factors affecting solubility and rate of solution

- a. Nature of solute and solvent

- (1) Structural similarity of solute and solvent
 - (2) State of subdivision of solute

- b. Temperature

- * (1) Heat of solution
 - (2) Le Chatelier's principle

c. Pressure

2. Colligative properties of solutions

- a. Vapor pressure
- b. Freezing point depression
- c. Boiling point elevation
- d. Osmotic pressure

VII. Colloidal dispersions

A. Definitions

- 1. Particle size
- 2. Dispersed phase and dispersion medium

B. Preparation

- 1. Dispersion
- 2. Condensation

C. Types

- 1. Sol
- 2. Emulsion
- 3. Gel
- 4. Acrosol

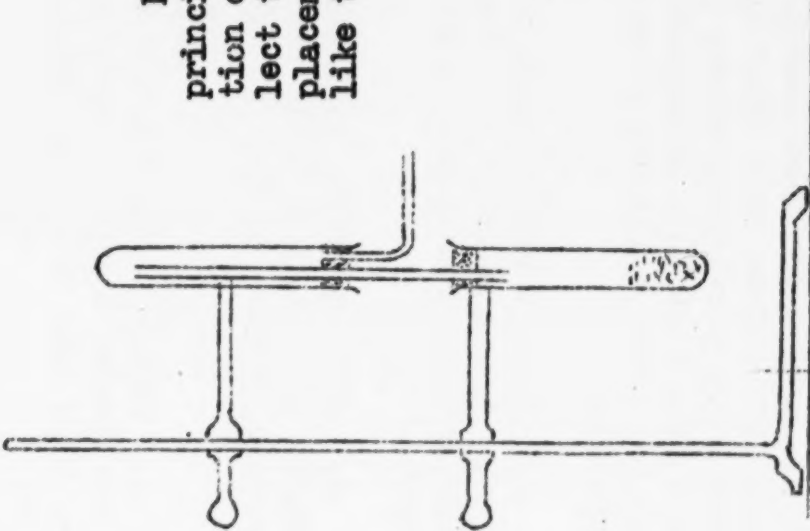
D. Characteristics

- 1. Tyndall effect
- 2. Electrical nature
- 3. Brownian movement
- 4. Protective action
- 5. Detergent action
- 6. Absorption

II. Suggested Procedures

CONTENT	TEACHING SUGGESTIONS	REFERENCES
I. Fundamental concepts *A. Enthalpy and entropy B. Characteristics of a system in equilibrium	*Develop the concept of energy loss and tendency toward disorder as opposing forces. To illustrate the equilibrium of the two fundamental tendencies use various examples such as the fact that the universe does not run down like a mechanical clock. A system in which two changes, each the exact opposite of the other, are produced and are proceeding at equal rates is called a state of dynamic equilibrium. Ask students to compare the example cited in Sienko and Plane or Dull, Metcalfe, and Williams with evaporation of water from an open beaker. In the open beaker evaporation will continue until all the water molecules have evaporated; in the closed system a state of dynamic equilibrium will be established. Display a saturated solution and ask the class to explain the equilibrium therein established. Ask a student to carry out and report on the following experiment: Prepare a saturated solution in a sealed jar. After equilibrium is established suspend a weighed broken fragment of the solute in the solution. Reseal one jar. Every three days remove the fragment and reweigh. Note the changing shape of the fragment as it acquires a geometric form. The fact that the weight remains constant but the shape changes shows that the system is in dynamic equilibrium. The difficulties encountered in this experiment with regard to temperature	Andrews and Kokes <u>University Chemistry</u> <u>Vol. 1</u> pp. 258-271, 385-434 Ibid. pp. 349-359 Sienko and Plane <u>Chemistry</u> pp. 163-165 Dull, et al. <u>Modern Chemistry</u> p. 297 Markham and Smith <u>General Chemistry</u> p. 75

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	control and evaporation will lead naturally to a discussion of the characteristics of a system in equilibrium. They will also point up the need for controls. (Assign this project two months prior to time of use.) Le Chatelier's principle states that if a stress is applied to a system in equilibrium, the system readjusts to reduce the stress. The second law of thermodynamics is stated in a general way as follows: All systems tend to approach a state of equilibrium. Introduce these two principles to the class. *Point out to high ability students that the second law is important because it deals specifically with the opposing quantities of enthalpy and entropy. Ask the class to enumerate the requirements for a state of equilibrium in the preceding crystal "repairing" experiment. Include constant temperature, closed system, and concentration of solvent. Have students predict how the system will shift in response to changes in conditions. Give them other examples to explain such as: 1. Adding ice to a beaker of water 2. Heating one end of a glass tube 3. Letting gas escape from a balloon	
1. Le Chatelier's principle 2. Factors affecting equilibrium		

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	Demonstrate the Le Chatelier principle by the thermal dissociation of nitrogen (IV) oxide. Collect the NO₂ by the downward displacement of air using an apparatus like that in the sketch.  Apparatus for generating and collecting nitrogen (IV) oxide.	Alyea and Dutton <u>Tested Demonstrations in Chemistry</u> p. 79

CONTENT	TEACHING SUGGESTIONS	REFERENCES
C. Kinetic-molecular theory 1. Interacting forces	*In classes of high ability introduce the topic in the following manner: a. Review the idea that plasma, gas, liquid, and solid states differ from each other in kinetic energy of particles, forces among particles, order, and interparticle distance. Mention the fact that at temperatures approaching 6000°C molecules no longer exist and atoms are being stripped of their electrons. b. Discuss vibrational, rotational, and translational motion. Have a student read Andrews and Kokes on molecular motion and use atomic models in a class demonstration on the subject. c. Show the film, "Vibrations of Molecules" and help students to develop a table showing the types of motion occurring in each of the four states of matter. d. Review the types of forces acting between particles: van der Waals, dipole-dipole, hydrogen bonds, and primary bonds. Show which ones of these forces are acting in each physical state. e. Have students use a handbook in making a table of densities of various substances in the solid, liquid, and gaseous states. A comparison of the densities will show	CBA Chemistry, Vol. I pp. 87-118 Andrews and Kokes <u>Op. cit.</u> pp. 251-258 Baltimore County Film #591.36 "Vibrations of Molecules" Dull, et al. <u>Op. cit.</u> pp. 30-31

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	that the transition from solid to liquid involves very little increase in volume whereas the liquid to gas change involves a great increase in volume. This fact indicates that bonds are only weakened in the solid-liquid change and the interparticle distances are not greatly increased, but that the liquid-gas transition involves the breaking of bonds, i.e. interparticle distances are increased indefinitely. Use values for heats of fusion and of vaporization as evidence supporting these assumptions. With regular classes use the following approach: - Review the states of matter and the factors which cause changes of state. Present the concept of plasma as a fourth energy state. Discuss particle distance and energy relationships among the three states of hydrogen oxide: ice, water, and water vapor. Perform the indicated demonstration (5-1) given in Alyea and Dutton. - Stress the energy relationships of the states of matter by demonstrating what happens when pressure is applied to a piece of ice and by boiling a small amount of water in a beaker. Discuss the energy changes that occur in each demonstration. - Place iodine crystals in a beaker. Cover with an evaporating dish so that the lip of the dish coincides with the spout of the beaker. Warm the beaker. The iodine will vaporize and recrystallize on the cold evaporating dish. Before the iodine was warmed attractive forces held it in the crystalline state. When heat is added the magnitude of the dispersive force overcomes the attractive force. The opposite occurs when the	Alyea and Dutton Op. cit. p. 13

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Density and expansion coefficient	vapor is crystallized. Use this demonstration to show that forces of attraction and dispersion are constantly in opposition. d. Display a collection of naturally-occurring crystalline solids. Use a microprojector or microscopes to show students crystals of salt, iodine, and alum. Discuss the order of particles in solids, liquids, and gases. Review changes of state in terms of increasing heat. solid $\longrightarrow$ liquid $\longrightarrow$ gas (endothermic) Changes in temperature alter the energy of a system. The addition of heat (kinetic energy) increases the molecular motion so that the forces binding particles in an orderly manner are overcome. Melt sulfur, iodine, and lead. If a small quantity of iodine will not liquefy, increase the amount used. Solidify mercury and bromine in a dry ice-acetone mush. Demonstrate cooling by evaporation. Pour acetone, ethyl alcohol, etc. on the hands of students in the front row. Perform the demonstration described by Alyea in activity 5-65s (c). Ask the class why at room temperature some substances are solids, some liquids, and some gases. Discuss in terms of types of binding forces. Describe van der Waals forces. Use the trends in physical states of the halogens as a concrete example. Discuss relative densities of gases, liquids, and solids. Point out that density for a liquid or solid is given in g/ml whereas gas density is given in g/l. Specific gravity of liquids and solids is given with water at 4°C as the standard (density/1g/ml) whereas the specific gravity of a gas is given with air at STP as the standard (density/1.29g/l).	Ibid. p. 107 Sienkp and Plane Op. cit. (text) pp. 176-178, 151-153

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	*Show that the coefficient of expansion of a liquid or solid is peculiar to the substance whereas in a gas it depends on conditions of temperature and pressure rather than on the identity of the gas. Review the one-constant function and inverse relationships in preparation for discussing gas laws. Compare the very slow rate of diffusion in solids, e.g. mutual diffusion in contiguous metals with the diffusion rate of liquids and of gases. Use suggested demonstrations. Review the concept of heat and specific heat. Show how the law of Dulong and Petit can be used in predicting the atomic weight of many solid elements. *Some students might profitably do graphic representations of the inverse relationship between atomic weight and specific heat or show that in an inverse relationship plotting the reciprocal of one of the functions results in a straight line. Review temperature scales. Make up and assign problems converting centigrade temperatures to degrees absolute.	Joseph et al. <u>A Sourcebook for the Physical Sciences</u> pp. 1-4 Kieffer and Fitzgerald <u>Selected Readings in General Chemistry</u> pp. 103-106 Garrett, et al. <u>Chemistry</u> pp. 186-189 Sackheim <u>Problem Solving in General Chemistry</u> pp. 19, 20, 23
3. Diffusion 4. Specific heat D. Fundamental conditions 1. Temperature		

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Pressure 3. Volume II. Special properties of gases A. Boyle's law	Low temperatures are of interest to students. Ask a member of the class to report on phenomena at low temperatures using the article, "Low Temperature Physics," by Davis. Make a mercurial barometer. Review methods of determining pressure and units for expressing pressure including the term atmosphere. Teach the class to read a mercurial barometer. Have a student report on the differences in design and operation of a mercurial and an aneroid barometer. Review the dimensions of volume in the metric system. Explain generally the interdependence of volume, pressure, and temperature Demonstrate the relationship between pressure and volume by inflating a balloon in a partial vacuum. Have the students explain what happens. Ask students to explain why a diver's lungs burst when he is suddenly forced to come to the surface without "pressure breaks." Follow with a lecture-demonstration of Boyle's law.	<u>Scientific American</u> Vol. 120, No. 6 pp. 30-39 Andrews and Kokes <u>Op. Cit.</u> pp. 272-324 Joseph, et al. <u>Op. cit.</u> pp. 334-336 Dull, et al. <u>Op. cit.</u> pp. 120-121 Garrett, et al. <u>Op. cit.</u> pp. 185-186

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Charles' Law	Plot results and have the class express the mathematical relationship between volume and pressure. Emphasize that this is an inverse relationship. *Derive the law in terms of fundamental units. #Drill the students on the pressure-volume relationship by using simple drawings of pistons and cylinders on the chalkboard. Start with a definite weight and volume. Then change the weight. Have students predict the new volume. Have students solve problems involving Boyle's law. Ask the students what effect temperature has on the volume of a gas. Verify their predictions by a demonstration using a balloon and a test tube. Introduce absolute temperature in the volume-temperature relationship by a laboratory	Resource Sheet 1, Unit One Bradbury, et al. <u>Op. cit.</u> p. 680 Lanford <u>Using Chemistry</u> pp. 82-83 Sienko and Plane <u>Op. cit.</u> (text) pp. 132-135 Markham and Smith <u>Op. cit.</u> pp. 45-46 Sackheim <u>Op. cit.</u> pp. 36-38, 46-48 Castka <u>Chemistry Problems</u> pp. 162-163, 167-168 Markham and Reilley <u>A Laboratory Manual for General Chemistry</u> pp. 47-50

CONTENT	TEACHING SUGGESTIONS	REFERENCES
C. Combined Laws	exercise in which the students verify Charles' law. Have the students plot their values and determine the point at which, theoretically, the volume of their gas would be zero. Ask the name of this point. According to Charles' law, volume is directly proportional to temperature. The ratio of temperatures should then equal the ratio of volumes. Have students calculate the ratios from a problem provided by the teacher. When students notice that the law does not hold for centigrade temperature, have them read to find out why. Discuss the absolute scale in relation to the centigrade scale and both in relationship to gas volumes. Return to the Charles' law experiment. Have the students convert their centigrade values to absolute values and substitute these in the equation $\frac{T_1}{V_1} = \frac{T_2}{V_2}$. Express Charles' law in statement form. *Have students perform the experiment, "Gases and Absolute Zero." Provide practice problems on Charles' law. *Explain the limited use of isothermic and isobaric laws to real situations since these are ideal conditions.	Dull, et al. <u>Op. cit.</u> pp. 122-124 Bradbury, et al. <u>Op. cit.</u> pp. 680-684 Slenko and Plais <u>Experimental Chemistry</u> pp. 71-79 Sackheim <u>Op. cit.</u> pp. 36-48

CONTENT	TEACHING SUGGESTIONS	REFERENCES
D. Equation of state and Avogadro's law	Recall the collapse of a can by atmospheric pressure. Ask the class to derive the expression for the combined gas law from Charles' and Boyle's laws. Express in terms of fundamental units. Give the students practice in finding a change in volume when both temperature and pressure vary. Have students set up pressure and temperature fractions so that they can see the relationship of these conditions to volume rather than merely plugging into an equation. For example, 100 ml of a gas at 740 mm and 293°K will occupy what volume at STP? The pressure is increased so consequently volume will decrease by a factor of $\frac{740}{760}$; the temperature is decreased so the volume will decrease by a factor of $\frac{273}{293}$. This method promotes understanding by avoiding the mechanical use of a formula. Summarize the basic gas laws by viewing the film, "Gas Laws and Their Applications." *Before deriving the equation of state it is necessary to make assumptions for the existence of a perfect gas. Call attention to the deviations in the pressure-volume data summarized in Sienko and Plane. Ask the students what conditions cause deviation from the laws, and why. Discuss van der Waals forces. Teach the Avogadro principle. Interest a student in making a gram-molar volume box as a teaching aid as described	Dull, et al. <u>Op. cit.</u> pp. 124-126 Sackheim <u>Op. cit.</u> pp. 38-40 Castka <u>Op. cit.</u> pp. 164-165; 168 Baltimore County Film #591.25 "Gas Laws and their Applications" Sienko and Plane <u>Op. cit.</u> (text) p. 134 University of Chicago <u>The Structure and Motion of Molecules</u> p. 136-142

CONTENT	TEACHING SUGGESTIONS	REFERENCES
R. Dalton's Law	in Alyea and Dutton, 3-10. *Derive the equation of state for 1 mole of any gas and solve for the value of R. Express in fundamental units. Emphasize the necessity for using correct units in problems. Have a student report on Cannizzaro's determination of molecular weights using the Avogadro principle. Have students perform the experiments, "Molar Volume of Oxygen" and "Molecular Weight of a Condensable Vapor." Point out the significance of pressure, temperature, and volume relationships in determinations of the molecular weight of gases. *Give students problems based on the equation of state. Relate and account for the preceding laws in terms of the kinetic-molecular theory. Show students how Dalton's law is used in correcting for vapor pressure in a gas collected over water. Have them solve problems making such corrections.	Alyea and Dutton <u>Op. cit.</u> p. 9 Sienko and Plane <u>Op. cit.</u> (manual) pp. 81-87 Dull, et al. <u>Laboratory Experiments in Chemistry</u> pp. 35-38 Castka <u>Op. cit.</u> pp. 139-142 Sackheim <u>Op. cit.</u> pp. 40-41 Garrett, et al. <u>Op. cit.</u> p. 190 Markham and Smith <u>Op. cit.</u> pp. 50-51

CONTENT	TEACHING SUGGESTIONS	REFERENCES
F. Gay-Lussac's law G. Graham's law	Review the law of combining volumes and the mole concept presented in Unit One. Have a drill session on volume-volume problems involving changes in temperature and pressure. Demonstrate Graham's law by the "Diffusion of Gases." Develop the algebraic expression of the law from this demonstration. *Express in fundamental units. (Resource Sheet 1, Unit One.) Assign problems from Sackheim. Have a student report on the separation of uranium isotopes by the diffusion method.	Sienko and Plane <u>Op. cit.</u> (text) pp. 137-139 Sackheim <u>Op. cit.</u> pp. 44-46 Markham and Reilley <u>Op. cit.</u> pp. 55-58 CBA <u>Op. cit.</u>, Vol. I p. 27 Sienko and Plane <u>Op. cit.</u> (text) p. 143 Markham and Smith <u>Op. cit.</u> pp. 40-42 Sackheim <u>Op. cit.</u> pp. 43-44 Glasstone <u>Sourcebook on Atomic Energy</u> pp. 200-204

CONTENT	TEACHING SUGGESTIONS	CONTENT
III. Special properties of liquids	Summarize the study of gases by showing the film, "Behavior of Gases." As a culminating activity have the students write a paragraph in which they show that the effect of pressure, temperature, and volume changes on gases is related to kinetic energy of particles, interparticle distance, and forces of attraction among particles. *For classes of high ability review the idea that liquids have definite volume, indefinite shape, and are relatively incompressible. Relate these properties to structural and kinetic factors. *Have students determine the density of several pure liquids and of the same liquid at different temperature by measuring weights and volumes. Have them use hydrometers and a handbook to check their experimental results. *Have students determine boiling points and melting points of several pure liquids and check their results with a handbook. Point out that boiling and melting points are used as identifying properties of pure substances. For regular classes review general properties of liquids by demonstrating incompressibility, density, indefinite shape, definite volume, diffusibility, etc. as indicated in the references. Compare the rates of diffusion in liquids and gases.	Sienko and Plane <u>Op. cit.</u> (text) pp. 160-167 Joseph, et al. <u>Op. cit.</u> pp. 2, 5 Sutton <u>Demonstration Experiments in Physics</u> pp. 105, 107, 112

CONTENT	TEACHING SUGGESTIONS	REFERENCES
A. Surface tension B. Capillarity C. Viscosity	Demonstrate the thermal expansion of liquids. Review the skin effect by floating a needle or razor blade on water and show how this phenomenon can be explained in terms of the intermolecular forces within the liquid which are greater than and different from those pulling from without. For additional demonstrations of surface tension see suggested references. Have a student read and report on the reference on soap bubbles. Discuss cohesion versus adhesion and show the relationship of meniscus shape to these forces. Demonstrate capillary action with different liquids and in tubes of different diameters. Explain that the height of the column is a function of the cohesive forces within the liquid. Ask students to predict the effect of temperature on the height of the column. If a viscometer is available have students determine relative viscosities of various liquids and the effect of temperature on the viscosity of a liquid. Show that the functional relationship of temperature and viscosity can be explained in terms of attractive versus dispersive forces.	Alyea and Dutton <u>Op. cit.</u> pp. 65, 99, 102-103 Joseph, et al. <u>Op. cit.</u> pp. 395-396 Hiller and Herber <u>Op. cit.</u> pp. 345-348 Boys <u>Soap Bubbles</u> Joseph, et al. <u>Op. cit.</u> pp. 10-14 <u>Ibid.</u> pp. 14-15 Markham and Smith <u>Op. cit.</u> pp. 65-68 Hiller and Herber <u>Op. cit.</u> pp. 338-344

CONTENT	TEACHING SUGGESTIONS	REFERENCES
IV. Solids A. Amorphous solids B. Crystalline solids 1. Methods of studying structure	*In classes of high ability review malleability, ductility, and hardness. Relate these properties to the structure of solids and interparticle attraction. Discuss the kinetics of solids, explaining that motion of particles in solids is even more restricted than in liquids. In regular classes display a variety of solids. Ask the students to list the general properties of solids. Review malleability, ductility, and hardness. Explain that amorphous solids are intermediate in orderliness of particles between liquids and solids and are, for this reason, sometimes called supercooled liquids. *Have students of high ability read the section on solids in one of the suggested references. Have a student report on methods of studying the structure of crystals as discussed in the PSSC monograph of some other reference.	Sienko and Plane <u>Op. cit.</u> pp. 168-170 Markham and Smith <u>Op. cit.</u> pp. 68-69 Garrett, et al. <u>Op. cit.</u> pp. 199-201 Markham and Smith <u>Op. cit.</u> pp. 68-73 Sienko and Plane <u>Op. cit.</u> pp. 168-180 Holden and Singer <u>Crystals and Crystal Growing</u> pp. 166-199

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Fundamental parameters a. Axial length b. Crystal angles 3. Crystallographic systems	Have students make models of the various crystallographic systems showing relative axial lengths, angles between axes, and the possible arrangements of particles in a ~~crystal~~. In regular classes have a student report on the crystalline structure of solids. Include in the report the basic crystallographic systems and relate the properties of solids to their structure. Display models of the crystallographic systems: Cubic, tetragonal, orthorhombic, monoclinic, triclinic, and hexagonal.	<u>Ibid</u> pp. 150-165 <u>Science and Math Weekly, Vol. I, No. 2</u> "Atoms, Molecules, Crystals" CBA <u>Op. cit.</u> pp. 105-106, 109 Markham and Smith <u>Op. cit.</u> pp. 69-72, 132-139 Kieffer and Fitzgerald <u>Op. cit.</u> pp. 35-37 Holden and Singer <u>Op. cit.</u> pp. 108-119

CONTENT	TEACHING SUGGESTIONS	REFERENCES
4. Forces determining structure V. Changes of state A. Order of particles B. Energy relationships 1. Solid₁ ↔ solid₂	To demonstrate several types of packing, have a student build and explain the model described in <u>Selected Readings in General Chemistry</u> Review the disordering process from the solid to gaseous state in terms of bonding and motion of particles In high ability classes assign reading in either Sienko and Plane or Markham and Smith. In regular classes have selected students read and report on this material. Discuss the transition of sulfur or phosphorus from one allotropic form to another. Have classes or individual students of high ability study and report on one or more of the following: ~~Encyclopedia~~ Britannica Filmstrips, "Crystals and their Deformations," "Relative Sizes of Ions," "Relative Sizes of Atoms," "Sizes and Shapes of Molecules," and "Shapes and Properties of Molecules."	Kieffer and Fitzgerald <u>Op. cit.</u> p. 42 EB Filmstrip "Packing of Atoms in Crystals" Markham and Smith <u>Op. cit.</u> pp. 54-63 Sienko and Plane <u>Op. cit.</u> pp. 176-178

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Solid $\rightleftharpoons$ Liquid a. Melting point and freezing point b. Heat of fusion c. Super-cooling	For regular classes these films are probably too difficult unless they are supplemented by considerable teacher explanation and possibly by student-prepared three-dimensional models. The chart in Sienko and Plane provides a helpful summary of this topic that could be used with regular classes. *In classes of high ability display simple heating and cooling curves. Discuss the slopes and plateaus in terms of increase and decrease of kinetic and potential energy. Show that molar heats of fusion and vaporization are quantitative measures of the attractive forces in a substance. *Have the class determine the heat of fusion of ice as a laboratory exercise. As a laboratory activity have the class cool some substances and plot the cooling curves. Include amorphous materials like paraffin or caramel. See Alyea and Dutton, activity 5-65s (b). Ask the class to draw heating curves and account for their general shape in terms of the kinetic-molecular theory. Discuss or have a student report on supercooled liquids. See, for example, the <u>Scientific American</u> article on glasses.	Sienko and Plane <u>Op. cit.</u> (text) pp. 176-178, 181-191 CHEM Study <u>Laboratory Manual</u>, <u>Vol. I</u> pp. 3-3 to 3.4 Joseph, et al. <u>Op. cit.</u> p. 409 Alyea and Dutton <u>Op. cit.</u> p. 107 Joseph, et al. <u>Op. cit.</u> pp. 412-413 <u>Scientific American</u> Vol. 204, No. 1 pp. 92-105

CONTENT	TEACHING SUGGESTIONS	REFERENCES
3. Liquid $\rightleftharpoons$ gas a. Boiling point- condensation point b. Vapor pressure	#With regular classes teach solid-liquid transitions by demonstrating the change of liquid lead and naphthalene to their solid states. Ask students to explain the energy factors involved to develop the concept of melting point and freezing point. #Divide the class into three groups. Have individual groups determine the heat of fusion of ice, the heat of condensation of water, and the freezing point of water. Discuss the laboratory results and calculations of each group with the whole class. Either assign a laboratory activity on distillation or demonstrate fractional distillation. Determine the boiling points of common liquids and check the laboratory results with handbook values. Explain that boiling points are sometimes used to identify liquids. Ask the class to explain why in a series of similar compounds boiling points increase as molecular weights increase. Perform various demonstrations of vapor pressure, boiling liquids under reduced pressure, use of manometers, etc. Relate vapor pressure and Raoult's law quantitatively. Have students perform suggested laboratory exercises in Markham and Reilley, and in Joseph.	Markham and Smith <u>Op. cit.</u> pp. 61-62 Markham and Reilley <u>Op. cit.</u> pp. 85-89, 93-95 Dull, et al. <u>Op. cit.</u> pp. 25-26 Alyea and Dutton <u>Op. cit.</u> pp. 57, 96, 101, 102 Joseph, et al. <u>Op. cit.</u> pp. 411-412 Markham and Reilley <u>Op. cit.</u> pp. 77-84

CONTENT	TEACHING SUGGESTIONS	REFERENCES
c. Heat of vaporization 4. Solid $\xrightleftharpoons{\text{gas; sublimation}}$ C. Equilibrium 1. Critical temperature and pressures	Ask a student to report on the operation of a vacuum drying oven. Show that the magnitude of vapor pressure is inversely related to the attractive forces between molecules and is dependent on temperature and pressure. Display some solids like iodine, dry ice, and camphor, and explain that these solids are unusual because of their extremely high vapor pressures. Recall the vaporization and condensation of iodine presented earlier in this unit. Show sublimation pressure by the demonstration from Alyea and Dutton. *Define critical temperature and critical pressure. Discuss the table in Sienko and Plane to show that critical temperature depends on the magnitude of the intermolecular attractive forces. #In regular classes discuss the liquefaction of gases and the production of liquid air. Define critical temperature noting that gases must be cooled to or below this temperature before they will liquefy.	Alyea and Dutton <u>Op. cit.</u> (text) p. 63 Sienko and Plane <u>Op. cit.</u> (text) pp. 153-154 Dull, et al. <u>Op. cit.</u> pp. 401-404

CONTENT	TEACHING SUGGESTIONS	REFERENCES
#2. Phase diagrams and triple point VI. Solutions A. Definitions 1. Solubility	*Assign reading in Sienko and Plane. A phase diagram summarizes the relation between the solid, liquid, and gaseous states of a given substance as a function of temperature and pressure. Follow through the examples in the text with the class and discuss phase changes, equilibrium lines, and triple points. *Ask a student to give a simple non-mathematical presentation of Gibbs phase rule. Assign reading in one of the suggested references. Define and give examples of solubility, solute, solvent, and solution. Enumerate the nine basic types of solutions: gas-gas, gas-liquid, gas-solid, liquid-gas, liquid-liquid, liquid-solid, solid-gas, solid-liquid, and solid-solid; and ask the class to give examples of each.	Sienko and Plane <u>Op. cit.</u> (text) pp. 186-191 Hiller and Herber <u>Op. cit.</u> pp. 401-408 Glasstone <u>Textbook of Physical Chemistry</u> pp. 465-478 Dull, et al. <u>Op. cit.</u> (text) pp. 242-253 Sienko and Plane <u>Op. cit.</u> (text) pp. 193-199 Markham and Smith <u>Op. cit.</u> pp. 74-81

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Concentration a. General (1) Dilute and concentrated (2) Unsaturated, saturated, supersaturated b. Standardized	In all classes emphasize that the general terms for expressing concentration are not quantitative and therefore have limited use. Define the terms and use a colored solute in water to illustrate dilute and concentrated solutions. Use equal masses of a relatively insoluble and a soluble salt in equal volumes of water to demonstrate that a saturated solution may be dilute or concentrated. Heat a saturated solution to show that saturation is a function of temperature and is, therefore, only a relative expression of concentration Use some or all of the demonstrations on solutions in the suggested reference to show the above relationships. Point out that in most laboratory situations the concentration of a solution must be quantitatively expressed and that different conventions are used for giving this information.	Garrett, et al. <u>Op. cit.</u> pp. 222-235, 249-250 Joseph, et al. <u>Op. cit.</u> pp. 154-162, 165-173 Weisbruch <u>Semimicro Laboratory Exercises in High School Chemistry</u> pp. 47-51

CONTENT	TEACHING SUGGESTIONS	REFERENCES
(1) Molar	Define a molar solution. Work sample problems on the board showing both the determination of the molarity of a given amount of solute and solvent and the calculation of the amounts needed to form a certain molarity. Assign practice problems on molarity and mole fraction.	Sackheim Op. cit. pp. 113-120
(2) Normal	Define a normal solution but reserve calculations for study in connection with acids and bases. Point out that the concentration of oxidizing and reducing agents is expressed in terms of molarity because the normality of an oxidizing or reducing agent is dependent upon the reaction.	Castka Op. cit. pp. 171-173
(3) Formal	Explain that the term formal should be used for solutions when the solute is ionic.	Joseph, et al. Op. cit. pp. 167-170
(4) Molal	Define and study molal solutions as preparation for the discussion of the colligative properties of solutions.	Castka Op. cit. pp. 180-183
(5) Per cent	Define and distinguish between per cent by weight and per cent by volume conventions in giving solution concentration. Assign problems.	Ibid. pp. 170-171 Ibid. pp. 173-174

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Solution equilibrium 1. Factors affecting solubility and rate of solution a. Nature of solute and solvent (1) Structural similarity of solute and solvent (2) State of subdivision of solute	Show the students some sugar and barium sulfate and call attention to the similarities of their physical appearance. Then demonstrate how their solubilities differ in water. Demonstrate that the solubility of fats is different in water and carbon tetrachloride. Note the useful generalization "like dissolves like," and show students how structural similarity between solute and solvent particles tends to result in greater solubility; for example, ionic solutes are more likely to be soluble in a polar substance such as water. Have students do one of the standard laboratory exercises on solutions and solubility suggested in the references.	McGill and Bradbury <u>Chemistry Guide and Laboratory Activities</u> pp. 77-82 Joseph, et al. <u>Op. cit.</u> pp. 155-158 Markham and Reilley <u>Op. cit.</u> pp. 107-113 CHEM Study <u>Op. cit.</u>, Vol. I. (manual) pp. 10-1. to 10-2

CONTENT	TEACHING SUGGESTIONS	REFERENCES
b. Temperature *(1) Heat of solution	Ask students to predict the effect of increased surface area on rate of dissolving. To verify the prediction, carry out the following activity suggested by Wolthuis in the <u>Journal of Chemical Education</u>: Put a lump of a solid in one test tube and grind up the same amount of the solid and put it in another test tube. Add 5 ml of water to each and shake. Which dissolves more quickly and why? Ask students to predict the effect of agitation on the rate of dissolving. To verify the prediction put equal amounts of copper sulfate in each of two test tubes. Add 5 ml of water to each. Shake one. Do not shake the other. Have students observe the rate of solution. Point out that agitation and the state of subdivision affect rate, but not degree of solution. *In classes of high ability assign reading as indicated. Define and discuss heat of solution relating it to change of solubility with temperature.	Kieffer and Fitzgerald Op. cit. pp. 110-111 <u>Journal of Chemical Education</u> Vol. 37, No. 2 Sienko and Plane Op. cit. pp. 209-211

CONTENT	TEACHING SUGGESTIONS	REFERENCES
(2) Le Chatelier's principle	Demonstrate Le Chatelier's principle by warming a solution saturated at room temperature or cooling an unsaturated solution until crystallization occurs. Have students perform a quantitative experiment on solubility and plot the curve. Give practice in interpreting solubility graphs and in solving problems. #In regular classes contrast the rate of formation of crystals in a saturated solution with that in a super-saturated solution. Gently heat water in a test tube. Ask students to explain the presence of gas bubbles on the side. This shows that the gas is less soluble in the liquid as the temperature increases. Have students perform the quantitative studies of solubility in the suggested references.	CHEM Study <u>Op. cit.</u>, Vol. I. pp. 11-1 to 11-2 Sienko and Plane <u>Op. cit.</u> (manual) p. 109 Bradbury, et al. <u>Op. cit.</u> pp. 102-103 Garrett, et al. <u>Op. cit.</u> pp. 225-228 Markham and Beilley <u>Op. cit.</u> pp. 115-121 MCA <u>Scientific Experiments in Chemistry</u> pp. 15-17

CONTENT	TEACHING SUGGESTIONS	REFERENCES
C. Pressure; Henry's Law D. Colligative properties 1. Vapor pressure 2. Freezing point depression	Have students experiment as directed in Alyea and Dutton (5-13) showing that the solubility of a gas is directly proportional to the pressure which is applied to it. In the follow-up discussion point out that pressure has little effect on the solubility of solids. Review equilibrium vapor pressure exerted by liquid water in a closed container as preparation for a demonstration. Illustrate by the bell jar experiment the fact that the vapor pressure of water is reduced by the presence of nonvolatile solute particles. Discuss the reason for this phenomenon using the kinetic-molecular theory. Review the definitions of boiling point and freezing point. Have a student report on various antifreezes. Explain freezing-point depression as a colligative property of a solution, the effect being due to a change in the vapor pressure. Introduce molal freezing-point depression of water (1.86°C). Emphasize the fact that this change depends on the presence of 6.023x10²³ particles and is independent of the nature of the particles. Work representative problems on the board. Discuss the effectiveness of various substances as antifreezes; e.g. Why is a salt such as Ba Cl₂ not used?	Alyea and Dutton <u>Op. cit.</u> p. 14 Sienko and Plane <u>Op. cit.</u> (text) pp. 163-165 Bradbury, et al. <u>Chemistry and You</u> p. 74 Sienko and Plane <u>Op. cit.</u> (text) pp. 197-199 Hillier and Herber <u>Op. cit.</u> pp. 453-466 Dull, et al. <u>Op. cit.</u> (text) pp. 268-269 Bradbury, et al. <u>Op. cit.</u> pp. 188-189

CONTENT	TEACHING SUGGESTIONS	REFERENCES
3. Boiling point elevation 4. Osmotic pressure	Have students determine molecular weights by the freezing-point depression method. Show that the presence of a nonvolatile solute changes the boiling point of a liquid and that boiling point is a function of vapor pressure. Introduce the molal boiling point elevation for water (0.52°C) and relate this to number of solute particles in solution. Assign laboratory work from Markham and Reilley on the colligative properties of solutions. Work representative problems and assign practice problems to students. Demonstrate the flow of a solute through a semi-permeable membrane and discuss osmosis as a colligative property of solutions.	Sienko and Plane <u>Op. cit.</u> (manual) pp. 103-108 Markham and Smith <u>Op. cit.</u>, p. 262 MCA <u>Op. cit.</u>, pp. 11-12 Markham and Smith <u>Op. cit.</u>, p. 262 Markham and Reilley <u>Op. cit.</u>, pp. 213-226 Markham and Smith <u>Op. cit.</u>, p. 265

CONTENT	TEACHING SUGGESTIONS	REFERENCES
VII. Colloidal dispersions A. Definitions 1. Particle size	Review the common knowledge about suspensions and solutions by showing and discussing mixtures of soil and water, sugar and water, etc. Develop with the class a chart similar to the one in Joseph comparing coarse suspensions, colloidal dispersions, and solutions. Demonstrate dialysis by placing small cubes of sugar, which have been coated with collodion just prior to the demonstration, in a beaker of warm water beside a beaker of water containing uncoated sugar cubes. The coated sugar cubes will rise to the surface while the dissolved sugar will pass through the membrane and the collodion in the cubes will remain on the surface of the water. Prepare a collodion dialyzer in a erlenmeyer flask. Introduce starch suspension and sodium chloride solution and suspend in a large beaker of distilled water. Show the class confirmatory tests for starch and the chloride ion in a test tube and then test the water surrounding the collodion dialyzer for the presence of these ions. This will lead to a discussion of particle size. Define colloidal particles as having a size of approximately 10⁻⁹ to 10⁻⁶ meters, between those of a suspension and a solution. Show that a significant property of colloidal dispersions is the enormous surface area presented by particles in this state of subdivision. Cut a 1 cm cube from a synthetic sponge. Prepare a square of paper having an area corresponding to the surface area of the cube (6cm²). The increase of sur-	Joseph, et al. Op. cit. pp. 158-159

CONTENT	TEACHING SUGGESTIONS	REFERENCES																								
2. Dispersed phase and dispersion medium	face area that results from dividing the cube into eight equal smaller cubes can be demonstrated without actually cutting the cube. Use squares of paper of increasing size. The square of surface area corresponding to the first subdivision would be 12 cm² and the second 24 cm². The following table summarizes the area increments for a series of subdivisions. <table border="1"> <thead> <tr> <th>Length of Side (cm)</th><th>Number of Cubes</th><th>Area (cm²)</th></tr> </thead> <tbody> <tr> <td>1.</td><td>1</td><td>6</td></tr> <tr> <td>.5</td><td>8</td><td>12</td></tr> <tr> <td>.25</td><td>64</td><td>24</td></tr> <tr> <td>.125</td><td>512</td><td>48</td></tr> <tr> <td>.0625</td><td>4096</td><td>96</td></tr> <tr> <td>.03125</td><td>32,768</td><td>192</td></tr> <tr> <td>.015625</td><td>262,144</td><td>384</td></tr> </tbody> </table> In preparation for their use in the demonstration of properties of colloids define dispersed phase and dispersion medium.	Length of Side (cm)	Number of Cubes	Area (cm ²)	1.	1	6	.5	8	12	.25	64	24	.125	512	48	.0625	4096	96	.03125	32,768	192	.015625	262,144	384	
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CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Preparation 1. Dispersion 2. Condensation C. Types 1. Sol 2. Emulsion 3. Gel 4. Aerosol D. Characteristics	Discuss generally the methods of breaking coarse material and coagulating finer material into the colloidal size. Use the chalkboard or a homemade chart in developing with the students the eight possible combinations of physical states. (A gas in a gas can be only a true solution.) Present the special names of the four most important types of colloidal dispersions and display examples. Ask students to categorize common substances; e.g. froth on carbonated drinks, mayonnaise, jelly, soap from an aerosol can, and milk. Demonstrate the properties of gels by performing some of the suggested experiments by Alyea and Dutton. The properties of colloids can be illustrated through demonstrations and individual laboratory activities according to the preference of the teacher.	Bradbury, et al. <u>Op. cit.</u> p. 410 Dull, et al. <u>Op. cit.</u> (text) pp. 453-467 Alyea and Dutton <u>Op. cit.</u> p. 151 Markham and Reilley <u>Op. cit.</u> pp. 335-340 Alyea and Dutton <u>Op. cit.</u> p. 151 Young <u>Practice in Thinking</u> p. 60 Markham and Reilley <u>Op. cit.</u> pp. 329-333

CONTENT	TEACHING SUGGESTIONS	REFERENCES
1. Tyndall effect 2. Electrical nature 3. Brownian movement 4. Protective colloids	Prepare a sol and demonstrate the tyndall cone as indicated in references. Compare to a true solution. Discuss colloidal stability due to like charges and explain how such colloids can be preserved or coagulated. Explain the purpose of dialysis. Demonstrate the effectiveness of dialyzing a $\text{Fe}(\text{OH})_3$ sol, prepared as in 1., by showing that: a) the $\text{Fe}(\text{OH})_3$ does not diffuse through the membrane; b) the Cl^- (true-solution-size particle) does diffuse through as shown by the formation of a white precipitate upon addition of Ag^+ to the container of water; c) coagulation occurs if the sol is not dialyzed promptly; and d) the dialyzed sol can be precipitated by addition of a solution containing charged particles. Discuss and/or demonstrate the migration of colloidal particle in an electric field as another evidence that some colloids are charged. Discuss colloidal stability due to Brownian movement. Demonstrate, using a microscope or a microprojector. Discuss the stability of colloidal particles due to a protective layer of a material such as gelatin. Demonstrate by mixing 5 ml of approximately 0.025 N K_2CrO_4 and 0.05 Ag NO_3. Repeat adding 10 drops of hot 10 per cent gelatin solution to 10 ml portions of each reagent before mixing. Have students observe the rate of precipitation.	Alyea and Dutton <u>Op. cit.</u> p. 50 Alyea and Dutton <u>Ibid.</u> pp. 49-50 Sienko and Plane <u>Op. cit.</u> (text) pp. 233-235 Alyea and Dutton <u>Op. cit.</u> p. 50

CONTENT	TEACHING SUGGESTIONS	REFERENCES
5. Detergent action 6. Adsorption	Discuss the reason for the grease-cutting action of soaps and detergents. Diagram on the board an oil particle surrounded by soap. Show that the relative smallness of the hydrocarbon end of the soap molecules causes the oil to be formed into droplets. Have students recall the increase in total surface area with the division of the substance into small particles. Explain the mechanism and uses of adsorption. Demonstrate the effectiveness in removal of color from a solution by shaking powdered charcoal with a dye solution and comparing the color to the original. As a summary of the topic, show one of films, "Colloids" or "The Colloidal State." As a summarizing activity for the unit have students analyze the interacting and opposing factors in the transition of matter from the solid state through liquids and gases to the state of highest energy, plasma. Begin by considering fundamental forces: in classes of high ability consider entropy	Garrett, et al. <u>Op. cit.</u> p. 580 Bradbury, et al. <u>Op. cit.</u> p. 414 Markham and Smith <u>Op. cit.</u> p. 527 Baltimore County Films #590.85 "Colloids" #591.86 "The Colloidal State"

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	and enthalpy; in regular classes attractive and dispersive forces. As a means of relating the interactions within a single state to the overall trends of basic opposing forces, develop with the students a summarizing scheme such as the one below. <u>DISRUPTIVE FORCES</u> Kinetic energy Vibrational Rotational Translational Coulombic repulsions <u>ATTRACTIVE FORCES</u> Nuclear Primary bonds Ionic Covalent Metallic Secondary Hydrogen Dipole-dipole Coulombic attractions Van der Waals	

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	Organize the content for the scheme by asking students to do the following: 1. List the interacting forces within each physical state. 2. Compare the relative strengths of attractive forces to show that the gaseous state is the most probable state but also the most unstable. 3. Compare rate of diffusion, compressibility, and density in solids, liquids, and gases accounting for their differences in terms of the kinetic-molecular theory. 4. Tell what happens when a solid is liquefied. Answer in terms of bonding, order, interparticle distance, and density. 5. Cite an example of a change of state and explain the change in terms of reestablishing the equilibrium between entropy and enthalpy.	

III. Bibliography

A. Books

Alyea, Hubert N. and Dutton, Frederic B. (eds). Tested Demonstrations in Chemistry. Easton, Pennsylvania: Division of Chemical Education of the American Chemical Society. 1960

Boys, C.V. Soap Bubbles. New York: Doubleday Book Company. 1959

Glasstone, Samuel. Sourcebook on Atomic Energy. New York: D. Van Nostrand Company, Inc. 1950

_____. Textbook of Physical Chemistry. New York: D. Van Nostrand Company, Inc. 1946

Holden, Alan and Singer, Phyllis. Crystals and Crystal Growing. Garden City, New York: Doubleday Anchor Books. 1960

Joseph, A., Brandwein, P.F., Morholt, E., Pollack, H., and Castka, J.F. A Sourcebook for the Physical Sciences. New York: Harcourt, Brace and World, Inc. 1961

Lanford, Oscar E. Using Chemistry. New York: McGraw-Hill Book Company, Inc. 1955

Manufacturing Chemists Association, Inc. Scientific Experiments in Chemistry. New York: Henry Holt and Company. 1959

Selected Studies in the Physical Sciences for Natural Sciences I: The Structure and Motion of Molecules. Chicago, Illinois: The University of Chicago Press. April 1959

Sutton, Richard M. Demonstration Experiments in Physics. New York: McGraw-Hill Book Company, Inc. 1938

B. Periodicals

"Atoms, Molecules, Crystals" Science and Math Weekly 1:16-17, January 18, 1961

Describes the structures of various crystalline substances and the bonds within them.

Davis, H. "Low Temperature Physics," Scientific American 120:30-39, June 1949

Examines physical phenomena at temperatures approaching absolute zero.

Greene, Charles H., "Glass," Scientific American
204:92-105, January 1961

Discusses the structure of glass as an example of a supercooled liquid; describes various types of glass.

C. Audio-visual aids

1. Films

Colloids (sound, black and white, 11 minutes. Free Central Film Library, Baltimore County Public Schools, Towson Senior High School, Towson 4, Maryland)

Gives a pictorial portrayal of colloidal suspension, using as examples fog, whipped cream, smoke, clay, and India ink.

Gas Laws and Their Applications (sound 15 minutes. Free, Central Film Library, Baltimore County Public Schools, Towson Senior High School, Towson 4, Maryland)

Gives basic and fairly simple presentation of laws describing the behavior of gases.

Vibrations of Molecules (sound, 11 minutes. Free, Central Film Library, Baltimore County Public Schools, Towson Senior High School, Towson 4, Maryland)

Shows in animation the relationship between the structure of a molecule and its modes of vibrations; illustrates the existence of discrete vibrational energy levels.

2. Filmstrips

Crystals and Their Deformations (24 frames, color, silent with text. \$6.00 Encyclopedia Britannica Films, Inc., 1150 Wilmette Avenue, Wilmette, Illinois)

Illustrates crystal deformations by use of molecular models.

Packing of Atoms in Crystals (25 frames, color, silent with text. \$6.00 Encyclopedia Britannica Films, Inc., 1150 Wilmette Avenue, Wilmette, Illinois)

Depicts different types of crystal structure by use of molecular models.

Relative Sizes of Atoms (29 frames, color, silent with text. \$6.00 Encyclopedia Britannica Films, Inc., 1150 Wilmette Avenue, Wilmette, Illinois)

Illustrates the size of atoms by use of styrofoam models.

Relative Sizes of Ions (25 frames, color, silent with text.
\$6.00 Encyclopedia Britannica Films, Inc., 1150 Wilmette
Avenue, Wilmette, Illinois)

Shows and compares sizes of ions and atoms.

Shapes and Properties of Molecules (26 frames, color,
silent with text. \$6.00 Encyclopedia Britannica Films
Inc., 1150 Wilmette Avenue, Wilmette, Illinois)

Relates the properties of molecules to their shape.

Sizes and Shapes of Molecules (30 frames, color, silent
with text. \$6.00 Encyclopedia Britannica Films Inc.,
1150 Wilmette Avenue, Wilmette, Illinois)

Relates the shapes of molecules to their size.

Resource Sheet 1

SUGGESTIONS FOR INDEPENDENT STUDY

1. Have a student investigate and report on the historical backgrounds of kinetic-molecular theory. The University of Chicago publication, The Structure and Motions of Molecules, contains an excellent section on the motions of molecules.
2. Have a student construct a working model of a Cottrell precipitator.
3. Have a student report on the physical changes in an electric refrigerator making special reference to the energy changes involved in the processes.
4. Have a student prepare and demonstrate to the class cardboard models of the thirty-two crystal classes. Directions can be found in Holden and Singer, Crystals and Crystal Growing, page 284.

UNIT FOUR

INORGANIC REACTIONS

I. Scope of the Unit

In this unit knowledge of structure and energy gained from the previous units is applied to a detailed study of the properties of inorganic systems. The unit is developed around two big ideas: 1) consideration of stresses on systems in equilibrium, and 2) energy changes in chemical reactions.

In the first topic the driving forces of a chemical reaction are considered. The theory of chemical reactions may be introduced by teaching collision theory and the related factors which contribute to or cause upset of a state of dynamic equilibrium. Topic I is written primarily for high-ability students; the depth of discussion of this section will depend on the ability and interest of the students.

Ionization may be introduced by considering the evidence for the theory provided by conductivity and changes in the freezing point and boiling point of solutions. The study should include the mechanisms involved in the dissolving of polar and ionic substances when water is the solvent. The modern theory as proposed by Debye-Hückel can be examined. The study of acids and bases supports the theory of ionization. Classical definitions can be used to introduce the characteristics of acids and bases, but attention should be given to the Brønsted-Lowry extension of the definitions. Indicators will be used as a tool in the study of neutralization, titration, pH, and hydrolysis.

A consideration of energy changes in electrochemical, thermochemical, and photochemical reactions will terminate the unit.

Inorganic Reactions

*I. Energy and chemical change

- *A. Energy
- *B. Heat of reaction
- *C. Heat of formation
- *D. Bond energy
- *E. Driving forces

- *1. Energy changes
- *2. Entropy changes
- *3. Free energy

*F. Predictions of reactions

II. Chemical kinetics

A. Reaction rate

1. Factors affecting reaction rate

- a. Nature of reactants
- b. Concentration of reactants
- c. Temperature
- d. Catalysis

2. Rate laws

*B. Collision theory

III. Chemical equilibrium

A. Law of mass action

- 1. Development and use
- *2. Heterogeneous equilibria

B. Equilibrium changes

IV. Ionization

A. Ionization theory

1. Historical development: Arrhenius

- a. Conductivity
- b. Freezing and boiling point changes

2. Reactions

- a. Ionization and dissociation
- b. Degree of ionization
- c. Ionization of H_2O

3. Modern theory: Debye-Hückel

B. Aqueous solutions

1. Acids and bases

- a. Properties and nomenclature of acids and bases
- b. Proton-donor-acceptor: Brønsted-Lowry
- c. Electron-donor-acceptor: G.N. Lewis
- d. pH

2. Neutralization

- a. Definition
- b. Salts
- c. Titration; indicators
- d. Hydrolysis
- e. Common-ion effect
- *f. Buffers

3. Solubility product

4. Qualitative analysis

V. Energy changes in chemical reactions

A. Principles of electron exchange

B. Electrochemistry

1. Chemical to electrical energy

- a. Galvanic cell
- b. Dry cell
- c. Lead storage battery
- d. Other cells

2. Electrical to chemical energy

- a. Electrolysis
- b. Faraday's law

*3. Oxidation-reduction potentials

4. Corrosion

#C. Thermochemistry

1. Definitions

2. Heat of reaction

- a. Heat of formation
- b. Law of Hess

D. Photochemistry

1. General considerations

2. Selected photochemical reactions

- a. Formation of ozone
- b. Photography

CONTENT	TEACHING SUGGESTIONS	REFERENCES
*I. Energy and chemical change *A. Energy *B. Heat of reaction	The introductory topics in this unit present concepts that are essential to an understanding of reaction theory but that are difficult to deal with in any depth. For regular classes this material could be omitted entirely or parts of it presented in a non-rigorous manner. With high-ability students topic I might be covered in two or three class periods. Teachers who are not well versed in the topic will find the CBA and <u>Journal of Chemical Education</u> references especially helpful. *Review kinetic and potential energy. Discuss with students various manifestations of energy, such as heat and light, pointing out that chemical reactions may involve several forms of energy. The direct measurement of chemical energy is not possible. The energy must be determined by using some device which converts chemical energy into a measurable form. *Review the law of conservation of energy by pointing out that although the form of energy may be changed during a reaction, the total quantity is constant. *Define heat of reaction, noting that the change of energy in a reaction, but not the absolute energy of a system, can be measured. *Give examples of some heats of reaction. Use of the convention of describing an exothermic reaction as having a negative heat of reaction ($-\Delta H$) and an endothermic reaction as having a positive heat of reaction ($+\Delta H$) is consistent with the conventions used in the free energy discussion to follow.	CBA <u>Chemistry, Volume I</u> pp. 169-173 Hiller and Herber <u>Principles of Chemistry</u> pp. 555-561 Markham and Smith <u>General Chemistry</u> pp. 388-390 CBA Op. cit. pp. 173-178

CONTENT	TEACHING SUGGESTIONS	REFERENCES
*C. Heat of formation *D. Bond energy	$\text{H}_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{H}_2\text{O}, \Delta H = -57.8 \text{ kcal/mole, rather than } \text{H}_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{H}_2\text{O} + 57.8 \text{ kcal. The second convention, however, is found in most general chemistry texts.}$ *Point out that the steps in which a change in energy take place are not important. Show how equations can be treated algebraically in determining heats of reactions of processes which are difficult to study experimentally. Assign practice problems, referring for examples to CBA. *Show the usefulness of heats of formation in determining heats of reaction without further experimentation. *Discuss the use of bond energies in determining energies of some reactions. Present examples of the calculations and have students practice using them. Discuss the use of bond energies in determining reaction energies of some chemical changes. Have the students investigate the selection of various substances as high energy fuels by calculating energy differences between the combustion and the exhaust gases. Have students select from the periodic table a pair of elements that meets the requirements listed in Resource Sheet 1. Refer students to the bond energy chart and have them record figures to support their selection. *Students of high ability should be able to predict the fuel value of various compounds by comparing bond energy differences between a propellant and its products. Have them make these calculations for complete oxidation of the propellant and for	CBA Op. cit. pp. 178-180 CBA Ibid. pp. 181-184 Resource Sheet 1 Gould <u>Inorganic Reactions and Structure</u> pp. 134-136 Pauling <u>Nature of the Chemical Bond</u> pp. 83-88

CONTENT	TEACHING SUGGESTIONS	REFERENCES
*E. Driving forces 1. Energy changes 2. Entropy changes 3. Free energy	reactions where the supply of oxidant is limited. Discuss the question of which reaction would develop the greater thrust. Use the following fuels and their oxidants: 1. ethyl alcohol + oxygen 2. octane + hydrogen peroxide 3. octane + nitric acid 4. hydrazine + oxygen 5. hydrazine + fluorine *From the discussion of bond energies and heats of reaction and formation students may think that only exothermic reactions are spontaneous. They are however, familiar with examples of endothermic reactions and the following section concerning the driving forces deals with this problem. Ask the students the question "How can you tell whether a reaction will occur?" After they have struggled with this for a while present the concepts of energy and entropy changes. Draw an analogy to a block of wood on a shelf as suggested in the <u>Journal of Chemical Education</u> article, "How Can You Tell Whether a Reaction Will Occur?" *Draw an analogy to the mixing of inert gases as suggested in the <u>Journal of Chemical Education</u>. *Define free energy for use in prediction of reactions in section F.	<u>Journal of Chemical Education</u> <u>Vol. 38, No. 7</u> <u>pp. 334-337</u> <u>Ibid.</u> <u>pp. 334-337</u>

CONTENT	TEACHING SUGGESTIONS	REFERENCES
a. Nature of reactants	Demonstrate the dependence of reaction rate on the nature of the reactants by showing the difference in rate of reaction of zinc in hydrochloric acid and acetic acid.	Garrett, et al. <u>Chemistry</u> pp. 269-271 Markham and Smith <u>Op. cit.</u> pp. 329-334 CBA <u>Op. cit.</u> pp. 193-200
b. Concentration of reactants	Demonstrate the effect of concentration on the rate of reaction by one of the activities suggested in Alyea and Dutton. Also show the effect of increased surface area, e.g. a dust explosion or the relatively rapid oxidation of steel wool compared to a steel plate.	Alyea and Dutton <u>Tested Demonstrations in Chemistry</u> p. 19, exp. 8-2, 8-3, 8-4, 8-6
c. Temperature	Demonstrate the effect of temperature on reaction rate as suggested in Alyea and Dutton.	<u>Ibid.</u> p. 19, exp. 8-5
d. Catalysis	Without prior discussion demonstrate the change in reaction rate that can be brought about by a catalyst as described in Alyea and Dutton. Show the film, "Catalysis." Use the film as a basis for discussing the several theories of catalytic action.	<u>Ibid.</u> p. 71 County Film #590.84 "Catalysis" Hiller and Herber <u>Op. cit.</u> pp. 651-655

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	Divide the class into three sections for laboratory study of the effects of concentration, temperature, and catalysis on reaction rate. Following the laboratory period select three students to present the data and describe the results of the experiments. In this way students will become familiar with each of the experiments.	MCA <u>Scientific Experiments in Chemistry</u> <u>Exp. 16, 18, 19</u>
*2. Rate laws	*Write on the chalkboard data such as is given on page 240 of Sienko and Plane and show how the rate law for the reaction is developed. Give other data for students to study and determine rate laws, as in Sienko and Plane, page 252.	Sienko and Plane <u>Op. cit. (text)</u> <u>pp. 243-251</u>
B. Collision theory	Develop the collision theory as in the references and with the film, "Introduction to Reaction Kinetics." The depth of discussion will depend on student interest and ability. Examine the theory concerning the existence of an activated complex following molecular collision. Point out that only a fraction of collisions result in a reaction; for reaction to take place the energy of activation must be available. Study the change of kinetic energy into potential energy needed to form the activated complex as described by the "potential-energy hill" and discuss the effect of temperature change and catalysis. *Use the theory to explain observed facts of chemical kinetics previously studied, i.e. factors affecting rate of reaction. Present the generalized rate expression, $\text{Rate} = k [A]^n [B]^m \dots$	Hiller and Herber <u>Op. cit.</u> <u>pp. 416-418</u> County Film #591.87 "Introduction to Reaction Kinetics" CBA <u>Op. cit.</u> <u>pp. 194-195</u>
		Hiller and Herber <u>Op. cit.</u> <u>pp. 635-639</u>

CONTENT	TEACHING SUGGESTIONS	REFERENCES
III. Chemical equilibrium A. Law of mass action 1. Development and use	noting, however, that a rate law cannot always be determined directly from the overall balanced equation. Review the concept of dynamic equilibrium by using one of the demonstrations described in the <u>Journal of Chemical Education</u>. Review equilibrium between states of matter, e.g. saturated solutions, water and water vapor. Emphasize the dynamic nature of such equilibria. Describe how it can be proved that the equilibrium is truly dynamic by a) the "healing" of a chipped crystal and b) by placing some solid containing radioactive atoms in a saturated solution and later observing that some radioactive particles are in solution. Discuss an example of a chemical reaction which can reach equilibrium, such as $2\text{Fe} + 3\text{H}_2\text{O} \rightleftharpoons \text{Fe}_2\text{O}_3 + 3\text{H}_2$, and show that this is analogous to the familiar physical equilibria. Show and discuss the film-strip, "Equilibrium." Develop the mass action expression from the generalized rate laws for a system in equilibrium, pointing out that this is not a rigorous development for reactions which take place in more than one step. Have students state the law of mass action in sentence as well as mathematical form. Ask the students to determine roughly the tendency of various reactions	<u>Journal of Chemical Education</u> Vol. 37, No. 6 p. 312 <u>Journal of Chemical Education</u> Vol. 37, No. 10 p. A677 Hiller and Herber Op. cit. pp. 120-122 Dull, et al. <u>Modern Chemistry</u> pp. 296-304. McGraw-Hill Filmstrip "Equilibrium" Sienko and Plane Op. cit. (text) pp. 254-262

CONTENT	TEACHING SUGGESTIONS	REFERENCES
to take place from their equilibrium constants. Do some calculations involving equilibrium and assign problems to students. Refer to text references for problems. Some unusual suggestions for presenting solution equilibrium are given in "Catalyzing the Approach to Equilibrium," <u>The Journal of Chemical Education</u>. #2. Heterogeneous equilibria B. Equilibrium changes	#Guide students to a realization that the concentration of solid and liquid substances does not change appreciably with pressure and temperature changes. It should therefore be clear that the concentration of solids or liquids in the mass-action expression is a constant and can be incorporated into K. #Changes in equilibrium may be studied in a general way by regular classes without discussing the law of mass action. Review Le Chatelier's principle. Discuss the effect on gaseous equilibrium of the following in terms of Le Chatelier's principle and the mass-action expression: a) addition of a reactant.	Hiller and Herber <u>Op. cit.</u> pp. 416-426 Markham and Smith <u>Op. cit.</u> pp. 334-338 Pauling <u>College Chemistry</u> p. 397 Garrett, et al. <u>Op. cit.</u> Appendix A, p. ix <u>Journal of Chemical Education</u> Vol. 23, No. 12 pp. 589-592 Sienko and Plane <u>Op. cit. (text)</u> pp. 262-264 Sienko and Plane <u>Op. cit. (text)</u> pp. 264-270

CONTENT	TEACHING SUGGESTIONS	REFERENCES
IV. Ionization A. Ionization theory 1. Historical development; Arrhenius a. Conductivity	b) removal of a reactant, c) volume increase and decrease, d) temperature increase and decrease in both endothermic and exothermic reactions. Note that a catalyst affects only the rate of a reaction, not its point of equilibrium. Refer to the impossible perpetual-motion machine, Sienko and Plane, page 270. To test students' understanding of equilibrium changes assign several examples of reversible reactions both gaseous and other, in which the effects of the stresses of heat and pressure changes are to be determined. Refer to the Haber process for one example, asking students to predict what conditions would be most satisfactory. Then note what conditions are used in industry and question students about why extremely high pressure and low temperature are not used. Introduce the theory of ionization by examination of such supporting evidence as boiling point and freezing point changes and conductivity of solutions. Demonstrate the conductivity of various substances as Arrhenius might have done. Refer to the resource sheet for suggested materials and questions to be raised. Guide students to conclusions that charged particles which are free to move must be present in solutions and in molten ionic solids, and that some substances provide more ions per mole than others. Introduce and define strong and weak electrolytes. Demonstrate the method of writing and balancing ionization equations.	Bradbury, et al. <u>Chemistry and You</u> pp. 232-233, 375-376 Markham and Smith <u>Op. cit.</u> pp. 238-239 Garrett, et al. <u>Op. cit.</u> p. 237 Resource Sheet 2 Dull, et al. <u>Laboratory Experiments in Chemistry</u> p. 59 Bradbury, et al. <u>Op. cit.</u> pp. 186-188

CONTENT	TEACHING SUGGESTIONS	REFERENCES
b. Freezing point and boiling point changes	Review the changes in the vapor pressure of a solvent due to the presence of a nonvolatile solute and the resulting changes in the boiling and freezing points of the solvent. Present some data showing that some solutes produce more change per mole than do others. Discuss how ionization can account for this. Review freezing point and boiling point problems. Students of high ability should study problems which require a knowledge of ionization such as the calculation of the freezing point of a 2 molal solution of BaCl_2. Have students determine freezing point and boiling point changes in the laboratory. Ask the students to summarize the evidence supporting ionization, and discuss how Arrhenius used this information to develop his theory. Assign a student to report on the work of Arrhenius, referring to the original papers if possible.	Bradbury, et al. <u>Op. cit.</u> p. 189 Sienko and Plane <u>Op. cit.</u> (manual) <u>Exp. E-16</u> Bradbury, et al. <u>Op. cit.</u> p. 189 Markham and Reilley <u>Laboratory Manual for General Chemistry</u> Experiment 45 <u>Journal of the American Chemical Society</u> Vol. 34, No. 4 p. 353

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Reactions a. Ionization and dissociation b. Degree of ionization c. Ionization of H₂O	Use diagrams to explain that water is polar due to its bond angles and is therefore an excellent solvent for ionic and polar substances because of coulombic forces of attraction. Distinguish between dissociation e.g., NaCl in H₂O, and ionization, e.g., HCl in H₂O. Show the filmstrip, "Ionization and Dissociation in Solution," to summarize the basic concepts of ionization. *Recall from the conductivity demonstration the various degrees of ionization. Using the dissociation constant, K_{diss}, demonstrate the calculation of species concentration and percent dissociation. Assign practice problems to the students. Discuss the fact that, although water does not appear to conduct when using the gross equipment of the school laboratory, it is partially ionized. $2H_2O \rightleftharpoons H_3O^+ + OH^-$. Indicate that the concentration of the hydronium ion and the concentration of the hydroxide ion are both $1 \times 10^{-7} M$ in pure water and that the product of the two is equal to 1×10^{-14} at 25°C. $[H_3O^+] = [OH^-] = 1 \times 10^{-7}$ $[H_3O^+] [OH^-] = 1 \times 10^{-14}$	Bradbury, et al. Op. cit. pp. 191-192 Encyclopedia Britannica Filmstrip "Ionization and Dissociation in Solution" Garrett, et al. Op. cit. pp. 241-242 Sienko and Plane Op. cit. (text) pp. 331-338 Castka Chemistry Problems pp. 193-195 Bradbury, et al. Op. cit. p. 236 Garrett, et al. Op. cit. p. 239

CONTENT	TEACHING SUGGESTIONS	REFERENCES
3. Modern theory; Debye-Hückel	Since the product of the concentrations of the ions is a constant at a given temperature it should be clear that the addition of one of the ions to water causes a decrease in the other. The approximation of the ion-product of water when used in connection with solution should be noted as explained in the <u>Journal of Chemical Education</u> reference. Have students practice writing and balancing ionic equations. Point out that experimental evidence led Arrhenius to believe that salts are not completely ionized. Then present the more modern theory according to Debye-Hückel. Concentrated solutions of electrolytes are still not well understood, however, and work is still being done on the problem, as noted in the Annual Review of Physical Chemistry article, "Solutions of <u>Electrolytes and Diffusion in Liquids</u>." Interest a student in studying the mechanisms and uses of ion-exchange columns. Refer to the bibliography for suggested references.	Sienko and Plane <u>Op. cit.</u> (text) p. 339 <u>Journal of Chemical Education</u> Vol. 38, No. 5 p. 260 Bradbury, et al. <u>Op. cit.</u> pp. 193-194 Garrett, et al. <u>Op. cit.</u> pp. 244-245 Sienko and Plane <u>Op. cit.</u> (text) p. 206 Annual Review of <u>Physical Chemistry</u> 1957 pp. 37-54

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Aqueous solutions 1. Acids and bases a. Properties and nomenclature of acids and bases b. Proton-donor-acceptors; Brønsted-Lowry	Introduce the properties of acids and bases through a student laboratory as suggested in Resource Sheet 3. Follow the laboratory session with a discussion of student results, tabulating the results on the board. Guide students to the realization that acidic properties must be due to the H_3O^+ ion and basic properties to the OH^- ion. Note differences of action of weak and strong and concentrated and dilute acids and bases. Emphasize the equilibrium between weak acid or base molecules and their ions. Discuss the formation of the copper (II) ion and differences in its intensity. Provisionally define an acid as a substance which gives H^+ as the only positive ion and a base as a substance which gives OH^- as the only negative ion when dissolved in water. Drill students on acid-base nomenclature. Assign questions and equations based on the discussion. Present the Brønsted-Lowry extension of the acid and base definitions and illustrate its usefulness in non-aqueous systems through selected reactions; e.g. $\text{NH}_4^+ + \text{NH}_2^- \rightleftharpoons 2\text{NH}_3$ acid base Provide several examples and ask students to identify which molecules or ions are acids and which bases; e.g. $\text{NH}_3 + \text{HOH} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$ base acid conjugate acid conjugate base	Resource Sheet 3 Bradbury, et al. Op. cit. p. 193 Gould Op. cit. pp. 82-84 Markham and Smith Op. cit. pp. 234-235

CONTENT	TEACHING SUGGESTIONS	REFERENCES
*c. Electron-donor-acceptor: G. N. Lewis 1. pH	*Describe the further extension of acid-base definitions proposed by Lewis. Students should be familiar with this definition, but will find the classical and Brønsted definitions more useful. Question students about their knowledge of pH. Develop the need for control of alkalinity or acidity in farming, medicine, fermentation, etc. If students are not familiar with logarithms develop the pH concept as in Bradbury, page 199. Demonstrate the calculation of whole-number pH and show the convenience of using pH in place of the hydrogen-ion concentration. Place the pH scale on the board, indicating the pH of common substances and indicators. *If students are familiar with logarithms a more rigorous approach should be used and calculations involving fractional pH should be carried out. If a pH meter is available teach a student to operate it and have him demonstrate it to the class. Ask a student to demonstrate the use of a soil-testing kit or a LaMotte comparator to illustrate how pH is important in everyday situations.	Sienko and Plane Op. cit. (text) pp. 209-210 Garrett, et al. Op. cit. p. 248 Bradbury, et al. Op. cit. pp. 199-200 Sackheim <u>Problem Solving in General Chemistry</u> pp. 121-123 Castka Op. cit. pp. 195-200

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Neutralization a. Definition b. Salts c. Titration; indicators	Write several examples of neutralization reactions on the board. Ask students to select the part of the equations which occur in every example and define this as neutralization: $\text{H}_3\text{O}^+ + \text{OH}^- \rightleftharpoons 2\text{H}_2\text{O}$. Discuss the fact that water is only slightly ionized and consequently we may expect that such a reaction will occur whenever H^+ and OH^- are brought together. Define salts as a product of an acid-base reaction. Use this opportunity to have the students practice writing and balancing equations, both molecular and ionic. Drill on nomenclature, reviewing the naming of acids, bases, and salts. An oral drill could be made into a game by matching one half of the class against the other. Recall the results of the acid and base experiment described in part 4 of Resource Sheet 3. Review normal solutions and teach calculation of equivalent weights. Develop the formula $N_1V_1 = N_2V_2$ and work some sample problems. Assign practice problems to students. Demonstrate proper titration procedures and have students practice methods in the laboratory as indicated in one of the references.	Bradbury, et al. Op. cit. p. 274 Sackheim Op. cit. pp. 64-67, 116-119 Sienko and Plane Op. cit. (manual) Exp. E-28 Dull, et al. Op. cit. (manual) Exp. 29, 30

CONTENT	TEACHING SUGGESTIONS	REFERENCES
d. Hydrolysis	In order to introduce the class to uses of the technique of titration interest a student in a project requiring titration and have him report to the class. See Resource Sheet 6 for suggestions. Assign a student to study various indicators and to report and demonstrate to the class. Have this student explain the reason for color change in indicators and how this change is used in titration. *Have students study a chart showing change in pH with progressive addition of an acid or base as in Sienko and Plane, page 341, and ask them to account for the very rapid change in pH around the equivalence point. Review the ionization of water and strong and weak acids and bases. Show, by writing equations, that the salt ions act as a stress on the water equilibrium, resulting in an equilibrium between the weak acid and/or base molecules and ions and between water molecules and ions. Have a laboratory exercise to show the reaction of salts with water. Refer to Resource Sheet 4.	Resource Sheet 6 McGill and Bradbury <u>Chemistry Guide</u> <u>Exp. 54</u> Cheronis and Stein <u>Semimicro Experiments in General Chemistry and Qualitative Analysis</u> pp. 123-128 Sienko and Plane <u>Op. cit. (text)</u> pp. 340-343 Bradbury, et al. <u>Op. cit.</u> pp. 235-240 Resource Sheet 4

CONTENT	TEACHING SUGGESTIONS	REFERENCES
e. Common-ion effect *f. Buffers	*Teach students to select the appropriate indicators for various titrations. Demonstrate and discuss the effect of adding a common ion to an aqueous solution in equilibrium, using one or more of the suggested demonstrations. Note that the reaction between FeCl_3 and NH_4CNS gives an example of complex ion formation. *Have students investigate the effect of change in concentration of one ion on equilibrium as suggested in Sienko and Plane. Extend the discussion of common-ion effect to include buffers. *Demonstrate buffer action. Point out the simultaneous equilibria involved. Discuss the importance of buffering agents in common substances such as blood, "Bufferin," and culture media.	Markham and Smith <u>Op. cit.</u> <u>p. 398</u> Dull, et al. <u>Op. cit.</u> (manual) <u>p. 75</u> Sienko and Plane <u>Op. cit.</u> (manual) <u>Exp. E-20</u> Garrett, et al. <u>Op. cit.</u> <u>Appendix A</u> <u>p. ix</u> Alyea and Dutton <u>Op. cit.</u> <u>p. 19</u> <u>Exp. 8-10, 8-11, 8-12</u> <u>Ibid.</u> <u>p. 67</u> and <u>Exp. 4-328</u> Joseph, et al. <u>A Sourcebook for</u> <u>the Physical Sciences</u> <u>p. 182</u>

CONTENT	TEACHING SUGGESTIONS	REFERENCES
#3. Solubility product	*Develop the expression for the solubility product constant and show how it can be used to predict whether precipitation will occur when two solutions are mixed. Assign practice problems to the students. Discuss an industrial process, such as soap manufacture, in which solubility is important.	Sienko and Plane Op. cit. (text) pp. 344-349 Castka Op. cit. pp. 201-204 Pauling College Chemistry pp. 439-449 Markham and Smith Op. cit. pp. 399-402
4. Qualitative analysis	Have students study the use of differing solubilities to separate and identify certain substances in the laboratory. Selected students should now be able to make up solutions for future laboratory exercises.	Markham and Reilley Op. cit. Exp. 66 Dull, et al. Op. cit. (manual) Exp. 68
V. Energy changes in chemical reactions A. Principles of electron exchange	Review oxidation and reduction reactions involving exchange of electrons. Show the filmstrip, "Balancing Equations" and follow with a drill on writing and balancing redox equations.	McGraw-Hill Filmstrip "Balancing Equations"

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Electro-chemistry 1. Chemical to electrical energy a. Galvanic cell	View the film, "Oxidation-Reduction", at this point and at the end of the electrochemical section, if possible. Variations and extensions of the demonstrations and experiments of this section can be found in Fowles. Place a piece of zinc in a CuSO_4 solution and have students observe what happens. Write the equation on the board and observe that electrons are transferred. Show how the movement of the electrons can be used by demonstrating a simple galvanic cell as in Alyea and Dutton. Contrast the action in a cell to electrolysis. Write the equation on the board and indicate how the activity series is used in making predictions. Help the students to see that the greater the difference in the activity of two metals, the greater the voltage.	Bradbury, et al. <u>Op. cit.</u> <u>p. 290</u> County Film #591.88 "Oxidation-Reduction" Fowles, et al. <u>The Science Masters!</u> <u>Book</u> <u>pp. 129-152</u> Sienko and Plane <u>Op. cit.</u> (text) <u>pp. 287-290</u> Bradbury, et al. <u>Op. cit.</u> <u>pp. 209-214</u> Alyea and Dutton <u>Op. cit.</u> <u>p. 62</u>

CONTENT	TEACHING SUGGESTIONS	REFERENCES
b. Dry cell c. Lead storage battery d. Other cells	Diagram and explain the action of a dry cell, contrasting it to a simple galvanic cell. Display a dry cell which has been cut lengthwise. Demonstrate a simple storage cell as in Alyea and Dutton. Diagram and explain the action of a lead storage battery. Question students about common information concerning a storage battery such as measuring the degree of charge, recharging, etc. Review specific gravity. At the discretion of the teacher other cells may be discussed. Ask students to report on the fuel cells. Assign another student to report on the contributions of Sir Humphry Davy to electrochemistry.	Ibid. p. 72 Scientific American Vol. 202, No. 6 pp. 106-116 Science and Math Weekly Vol. I, Issue 5 "Fuel Cells"
2. Electrical to chemical energy a. Electrolysis	Introduce electrolysis through the following demonstrations and a discussion of results: a. Connect electrodes placed in a U-tube filled with aqueous Cu Cl_2 to a DC source. Allow current to run for a few minutes. Have students observe the metal formed and note the odor of the gas formed. Diagram the apparatus, labeling the cathode and anode, and write down the ions present. Ask students to explain	Bradbury, et al. Op. cit. pp. 205-207

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	what has happened by indicating the movement of the ions and writing the correct equation. $\text{Cu}^{++} + 2\text{e}^{-} \longrightarrow \text{Cu}^0$; $2\text{Cl}^{-} - 2\text{e}^{-} \longrightarrow \text{Cl}_2^0$. b. Demonstrate as above the electrolysis of NaCl-aq. Allow students to observe the products and to discuss what the products may be. Ask them to devise methods for determining the identity of the gases. Diagram the apparatus, indicate the movement of the ions, and write the equations $2\text{Cl}^{-} - 2\text{e}^{-} \longrightarrow \text{Cl}_2^0$; $2\text{H}^+ + 2\text{e}^{-} \longrightarrow \text{H}_2^0 + 2\text{OH}^{-}$. State that this is a commercial method for preparing chlorine gas, hydrogen gas, and sodium hydroxide. Ask students to explain how to use the activity series to predict whether the metal ion or water will react at the cathode. c. Demonstrate electrolysis of Na_2SO_4-aq. to which a small amount of litmus powder has been added. Observe and identify the gases formed. Observe the changes in the litmus and ask students to explain the changes after writing the half-reactions. $2\text{H}_2\text{O} - 4\text{e}^{-} \longrightarrow \text{O}_2^0 + 4\text{H}^+$; $2\text{H}_2\text{O} + 2\text{e}^{-} \longrightarrow \text{H}_2^0 + 2\text{OH}^{-}$. Note that the water molecules, not the ions of water, are believed to react at the poles. Point out the relative volumes of gases formed if the Hoffman apparatus is used. Note that the reaction is simply the electrolysis of water with the positive and negative ions present to neutralize the charges on the ions formed in the reactions.	Sienko and Plane Op. cit. (text) pp. 279-286 Garrett, et al. Op. cit. pp. 282-285

CONTENT	TEACHING SUGGESTIONS	REFERENCES
b. Faraday's law	Using the activity series of metals and a brief activity series of nonmetals prepared from the above experiments and previous knowledge, have the students predict and write reactions of several combinations of ions, e.g. $\text{CuSO}_4\text{-aq.}$, and a mixture of NaCl and CuSO_4 in water. Diagram an electrolysis set-up as in Markham and Smith. Under each container write the weights of the metals formed after one faraday has been passed through the solutions. Ask the students to note the relationship between these weights. From this develop the law of Faraday introducing terms such as coulomb, faraday, and ampere and show how they are related. Avoid use of an involved formula into which all the information can be substituted. Work some sample problems to show how the law is used in calculation. Give the students practice problems. Assign a student to report on Michael Faraday using the <u>Scientific American</u> reference or some other source of information. Assign a student to electroplate an object with copper and to display and explain the apparatus to the class. He should give attention to factors such as pH, solution concentration, voltage, and current.	Markham and Smith Op. cit. pp. 280-281 Sienko and Plane Op. cit. (text) pp. 286-287 Sackheim Op. cit. pp. 124-127 <u>Scientific American</u> Vol. 189, No. 4 p. 90

CONTENT	TEACHING SUGGESTIONS	REFERENCES
#3. Oxidation-reduction potentials 4. Corrosion	Recall the discussion of redox (electrode) potentials. Present determination of redox potentials by diagramming various cells, such as Zn-H₂ and Cu-H₂, on the board and discussing the reactions which occur and the potentials which are developed. Teach the use of redox potentials in determining what reaction will take place in a cell and in finding the voltage developed. Assign practice problems to students. Have a student construct a simple cell for which the potential is known, display it to the class and compare the experimental value with the value given in a handbook. Emphasize the difference between electrode potential and ionization potential. See Resource Sheet 5. Indicate the electrolytic nature of corrosion. Ask students for examples and discuss methods of preventing corrosion by protective coatings of oxide, tin or chromium (low activity), or zinc (high activity); by attaching an active metal; and by impressing a negative charge. Ask students to report briefly on any other methods with which they are familiar. Refer to Science and Math Weekly, "The Nature of Corrosion" and "Protection Against Corrosion," for material suitable for student reports. Have students view and discuss the film "Corrosion in Action." Use a student laboratory to show the effect of strain in metal and of coupling of unlike metals.	Sienko and Plane Op. cit. pp. 291-296 Markham and Smith Op. cit. pp. 433-436 Resource Sheet 5 International Nickel Company Film "Corrosion in Action" Markham and Smith Op. cit. pp. 439-440 Science and Math Weekly Vol. I, Issues 12, 13 pp. 138-139, 150-151

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	As a culminating activity for the study of redox and ionization prepare a set of equations like the following to illustrate each type of reaction which has been studied: $\text{NaOH} + \text{HCl} \longrightarrow \text{NaCl} + \text{HOH}$ $\text{HCl} + \text{AgNO}_3 \longrightarrow \text{AgCl} + \text{HNO}_3$ $\text{Cu}(\text{OH})_2 + 2\text{HCl} \longrightarrow \text{Cu}(\text{NH}_3)_4^{++}$ $\text{Na}_2\text{CO}_3 + 2\text{HCl} \longrightarrow 2\text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$ $\text{C} + \text{O}_2 \longrightarrow \text{CO}_2$ $2\text{HgO} \longrightarrow 2\text{Hg} + \text{O}_2$ $\text{Zn} + \text{CaCl}_2 \longrightarrow \text{ZnCl}_2 + \text{Cu}$ Ask students to classify each reaction as either electron exchange or ion exchange. Have them examine the two resulting groups of equations and try to make further sub-divisions. By questioning the students try to have them arrive at the following organization: 1. Ionic reactions a. Acid-base b. Formation of a precipitate c. Formation of a gas d. Formation of a complex	Bradbury, et al. Op. cit. pp. 669-672 Hiller and Herber Op. cit. pp. 619-621 Sienko and Plane Op. cit. (text) pp. 428-429 Garrett, et al. Op. cit. pp. 286-289 MCA Op. cit. Exp. 24

CONTENT	TEACHING SUGGESTIONS	REFERENCES
#C. Thermo-chemistry #1. Definition #2. Heat of reaction #a. Heat of formation	2. Redox reactions a. Combination b. Decomposition c. Simple displacement Be sure that students note that an equilibrium may be reached in l.c., for example, if the system is closed, but that gas formation in an open system causes the reaction to go to an end. The following activities have been developed for regular classes which have not previously studied the topic. #Review calorie, kilocalorie, and BTU. Have a student report on how a bomb calorimeter is used to measure the amount of heat produced in a reaction. # Have students use the handbook to find heat values of various fuels and compare, in bar graph form, the cost per unit of the fuels used in the Baltimore area. Ask them to select the fuels theoretically most suitable for rocket use as described in Section I. C. of the teaching suggestions. #Define heat of formation. Using thermal equations for the formation of the hydrogen halides, ask students how the heat of formation can be used to predict the stability of the compounds.	Cheronis and Stein Op. cit. pp. 47-55 Bradbury, et al. Op. cit. pp. 225-227 Markham and Smith Op. cit. pp. 388-390 Resource Sheet 1 Bradbury, et al. Op. cit. p. 315 Sienko and Plane Op. cit. pp. 117-119

CONTENT	TEACHING SUGGESTIONS	REFERENCES
#b. Law of Hess D. Photochemistry 1. General consideration 2. Selected photochemical reactions a. Formation of ozone b. Photography	#State the Law of Hess. Show how the law can be used to calculate heats of reaction which are difficult to determine experimentally. See reference for examples. #Have a student determine the heat of a reaction using a simple ice calorimeter and report the results to the class. See <u>Journal of Chemical Education</u> for apparatus. If time is a factor, the section on photochemistry can be omitted. Explain how photochemical reactions are caused and the possible effects when photons are absorbed. Ask students where ozone is likely to be formed. Use the set of equations given in Markham and Smith to explain how ozone is formed from oxygen. Have a student report on the reactions which take place in the photographic process.	Markham and Smith <u>Op. cit.</u> p. 389 <u>Journal of Chemical Education</u> <u>Vol. 37, No. 12</u> p. 634 Markham and Smith <u>Op. cit.</u> pp. 529-537 Markham and Smith <u>Op. cit.</u> pp. 533-534 Bradbury, et al. <u>Op. cit.</u> pp. 310-312

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	In order to emphasize in a concrete manner two of the large concepts of the unit, energy and equilibrium changes, present the reactions of a number of industrial processes in equation form. Some examples are: a. The Haber process $N_2 + 3H_2 \rightarrow 2NH_3$ b. A blast furnace $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$ c. The electrolytic preparation of an active metal $Li^+ + 1e^- \rightarrow Li$ d. Recovery of bromine from salt water $2Br^- + Cl_2 \rightarrow Br_2 + 2Cl^-$ e. Extraction of magnesium from sea water $Mg^{++} + 2OH^- \rightarrow Mg(OH)_2 \downarrow$ f. Blueprinting $Fe^{++} \xrightarrow{\text{light}} Fe^{+++} \xrightarrow{\text{water}} Fe_3[Fe(CN)_6]_2$ blue	Garrett, et al. <u>Op. cit.</u> pp. 643-644 Pauling <u>College Chemistry</u> pp. 407-410

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	Ask questions about these reactions such as: How is the reaction classified in terms of electron-exchange and ion-exchange and their subcategories? In what form is the energy change manifested? Is the reaction endothermic or exothermic? What effect does the heat loss or gain involved in the reaction have on the process? How can the rate of the reaction be increased? What conditions are theoretically ideal for maximum yield? If theoretically ideal conditions are not used, why are they not? Does the reaction involve electrical energy? Note: All questions do not necessarily apply to each equation.	

III. Bibliography

A. Books

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Dowex: Ion Exchange. Midland, Michigan: The Dow Chemical Company. 1959 (free)

Fowles, G., Coulson, E.H., and Holt, C. The Science Masters' Book, Part II. London: John Murray. 1955

Harrison, Kenneth. A Guide-Book to Biochemistry. Cambridge, London: Cambridge University Press. 1959

Joseph, Alexander, Brandwein, P.F., Morholt, E., Pollack, H., and Castka, J.F. A Sourcebook for the Physical Sciences. New York: Harcourt, Brace and World, Inc. 1961

Pauling, Linus. College Chemistry. San Francisco: W.H. Freeman and Company. 1957

Riegel, E.R. Industrial Chemistry. New York: Reinhold Publishing Corporation. 1949

B. Laboratory Manuals

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Manufacturing Chemists Association. Scientific Experiments in Chemistry. New York: Henry Holt and Company. 1959

McGill, M.V. and Bradbury, G.M. Chemistry Guide and Laboratory Activities. Wilkes-Barre: Lyons and Carnahan. 1956

Nechamkin, Howard. Laboratory Problems in General Chemistry. New York: Thomas Y. Crowell Company. 1956

C. Periodicals

Austin, Leonard G. "Fuel Cells," Scientific American 201:72-92, October 1959

Tells how fuel cells convert chemical energy directly into electricity.

Batt, C.W. and Kowkabany, G.N., "Distance Factors in Paper Chromatography," Journal of Chemical Education 32:353-354, July 1955

Discusses a student project using paper chromatography.

Carmody, W.R., "Dynamic Equilibrium," Journal of Chemical Education 37:312, June 1960

Describes a dynamic equilibrium demonstration.

"Column Chromatography," Science and Math Weekly 1:70, February 15, 1961

Describes a simple method and experiments for column chromatography.

Dirkse, Thedford P., "The Ionization Constant of Water," Journal of Chemical Education 38:260, May 1961

Points out the approximation involved in $K_w = 1 \times 10^{-14}$ in solutions which are not extremely dilute.

"Fuel Cells," Science and Math Weekly 1:52-54, February 8, 1961

Compares various types of fuel cells to a galvanic cell and discusses possible uses.

Hildebrand, Joel E., "Catalyzing the Approach to Equilibrium," Journal of Chemical Education 23: 589-592, December, 1946

Suggests some ways to help the student visualize equilibrium concepts.

"Ion Exchange," Science and Math Weekly 1:38, February 1, 1961

Describes technique of ion-exchange columns.

Kondo, H., "Michael Faraday," Scientific American 189:90, October 1953

Describes the work of Michael Faraday.

Mac Wood, G.E., and Verhoek, F.H., "How Can You Tell Whether a Reaction Will Occur?" Journal of Chemical Education 38:334-337, July 1961

Discusses such topics as entropy and free energy. This is a very useful article describing the driving forces of reactions.

Mahan, Bruce H., "A Simple Ice Calorimeter," Journal of Chemical Education 37:634, December 1960

Explains how to set up an ice calorimeter and to use it to determine heats of reaction.

"Paper Chromatography," Demonstrations in Science, Texaco Research Center, The Texas Company, Beacon, N.Y.

Describes a simple method of paper chromatography.

"Paper Chromatography," Science and Math Weekly 1:154, April 5, 1961

Describes simple methods and experiments for paper chromatography.

"Protection Against Corrosion," Science and Math Weekly 1:146-147, April 5, 1961

Describes methods of combating corrosion and recent research exports in this area.

Robinson, R.A. and Stokes, R.H., "Solutions of Electrolytes and Diffusion in Liquids," Annual Review of Physical Chemistry, 8:1957, pp. 37-54.

Presents some of the recent theories of ionization.

Schmedel, Scott R., "Electrical Frontier of the Fuel Cell," Science Digest 50:40-45, August 1960

Describes the mechanisms of the fuel cell.

"Secular Equilibrium," Journal of Chemical Education 37:A676, October 1960

Outlines a demonstration of equilibrium.

"The Nature of Corrosion," Science and Math Weekly 1:138-139, March 29, 1961

Describes the chemical nature of corrosive processes.

"A Versatile Clock Reaction," Journal of Chemical Education 37:A221, April 1960

Describes a clock reaction which will demonstrate the effect of temperature, concentration, and catalyst on the rate of reaction.

Weissbart, Joseph, "Fuel Cells-- Electro-Chemical Converters of Chemical to Electrical Energy," Journal of Chemical Education 38:267-269, May 1961

Contains a description of a fuel cell including history and the thermodynamical considerations.

Williams, L. P., "Humphry Davy," Scientific American 202:106-116, June 1960

Concerns the contributions of Sir Humphry Davy.

D. Audio-visual aids

1. Films

• Catalysis (16 minutes, Free, Central Film Library, Baltimore

- " County Public Schools, Towson Senior High School, Towson 4, Maryland)

Illustrates the role of the catalyst in changing the rate of a reactions.

Corrosion in Action (sound, 70 minutes. Free, T.P. May, Corrosion Engineering Section, International Nickel Company, Inc., 67 Wall Street, New York, N.Y.)

Covers all aspects of corrosion.

Introduction to Reaction Kinetics (20 minutes. Free, Central Film Library, Baltimore County Public Schools, Towson Senior High School, Towson 4, Maryland)

Explains the collision theory of reaction in terms of activation energy; an excellent film suitable for all classes.

Oxidation-Reduction (20 minutes. Free, Central Film Library, Baltimore County Public Schools, Towson Senior High School, Towson 4, Maryland)

Presents several examples of oxidation and reduction reactions and illustrates electron exchange.

2. Filmstrips

"Balancing Equations by Electron Transfer," (40 frames, silent, with captions, McGraw-Hill Book Co., Text-Film Department, 330 W. 42nd. St., New York 36, New York)

Illustrates the oxidation-reduction method of balancing equations.

"Equilibrium" (40 frames, silent, with captions, McGraw-Hill Book Co., Text-Film Department, 330 W. 42nd. St., New York 36, New York)

Discusses several examples of chemical equilibrium.

Resource Sheet 1

EXOTIC FUELS

Many factors affect the choice of chemicals used as exotic fuels. First consideration is given to enthalpy differences between combustion and exhaust gases. Suitable substances must be of low molecular weight and low bond energy and must, upon reaction, yield products which are gases with high bond energies.

Energy Values for Some Single Bonds (kcal per gram-bond)

H-	C-	N-	O-	F-	Si-	S-	Cl-	Br-	I-	
104	99	84	110	135	81	81	103	87	71	-H
	82	63	82	103	69	66	78	65	57	-C
		32		56			37			-N
			33	44	89		49			-O
				37	128	71	61	61		-F
					43	61	66	73	51	-Si
						49	61	53		-S
							58	52	51	-Cl
								46	43	-Br
									36	-I

The energies for double or triple bonds between two atoms, (often evaluated by heats of combustion), are found to be somewhat higher than the corresponding single-bond energies:

C-C	82 kcal	C-N	63 kcal
C=C	146 kcal	C=N	123 kcal
C≡C	192 kcal	C≡N	194 kcal

Resource Sheet 2

CONDUCTIVITY

The following procedure will serve to demonstrate the presence of ions in solutions of electrolytes:

Set up a series of beakers containing tap water, distilled water, aqueous solutions of NaCl, HCl, $C_{12}H_{22}O_{11}$, C_2H_5OH , $HC_2H_3O_2$,

NaOH, NH_4OH , KNO_3 , solid NaCl and solid $C_{12}H_{22}O_{11}$. The conductivity of each of these

materials is to be determined with a conductivity tester. Have the students tabulate the names, formulas, and conductivity (good, poor, very poor) of these materials. After testing the first three or four samples ask the students to predict the degree to which succeeding samples will conduct and why.

Define electrolyte and nonelectrolyte, and then have the students categorize the tested materials.

Develop the theory of conductivity by posing the following:

1. Why do some solutions conduct?
2. Why do solids not conduct?
3. Solid sodium is a non-conductor; water is a non-conductor; an aqueous solution of sodium chloride is a good conductor. Explain why.
4. Define an ion. Why are some solutions poor conductors and others good conductors? Introduce and define the terms weak and strong electrolytes.
5. Solid sodium chloride is made up of ions in a lattice yet it does not conduct a current. Why?
6. According to the kinetic-molecular theory would a melted salt conduct a current? After discussion try this with fused sodium chloride.

Resource Sheet 3

ACIDS AND BASES

Use these suggestions to teach the general properties of acids and bases:

1. Prepare N solutions of HCl , H_2SO_4 , HNO_3 , $\text{HC}_2\text{H}_3\text{O}_2$, NaOH , KOH , NH_4OH , and 0.5N HCl .
2. Assign one acid and one base to each student and have them each do the following:
 - a. Test the acid and the base with red and blue litmus, noting any changes in color.
 - b. Drop a piece of zinc into a test tube and add a few ml of acid. Note the rate of reaction. If a gas is liberated test it with a burning splint. Identify the gas.
 - c. Repeat using copper.
 - d. Place enough copper oxide in a test tube to cover the bottom. Add about 4 ml of acid and heat gently for a few minutes. Cool and filter noting the intensity of color of the filtrate.
 - e. Place 4 ml of either 2 N or 0.5N HCl in a test tube and add base until the solution is neutral to litmus. How many ml of base were added?

Resource Sheet 4

pH, HYDROLYSIS, INDICATORS

The purpose of this resource sheet is to relate pH, hydrolysis, and indicators by a series of experiments.

To show a method of determining pH, place a few drops of each of the following solutions on a watch crystal. Test each solution with hydron paper and compare with the color chart. For each of the solutions record name, formula, concentration, pH, and hydrogen ion concentration.

- | | |
|----------------------------|----------------------------|
| (a) .01N hydrochloric acid | (e) .2N potassium chloride |
| (b) .01N acetic acid | (f) .2N aluminum sulfate |
| (c) .2N sodium acetate | (g) .2N sodium carbonate |
| (d) .2N ammonium chloride | |

To illustrate the principle of hydrolysis ask students to account for the difference in pH of .01N solutions of hydrochloric and acetic acid. Write hydrolysis equations for the salts and ask students to relate the equation to the experimentally determined pH.

The pH range of an indicator may be shown by putting 6 ml of water in each of two test tubes, adding a few drops of hydrochloric acid to one and a few drops of sodium hydroxide to the other. The addition to each of these solutions of four drops of phenol red will produce different colors. Another tube containing 6 ml of water plus four drops of phenol red should be prepared and breathed into through a glass tube until a color change occurs. Have students account for this change.

Pour 10 ml of .1N hydrochloric acid into a test tube. Dilute 1 ml of this solution with water to a volume of 10 ml. Make successive dilutions until there are six test tubes of decreasing concentrations of hydrochloric acid. To each of these tubes add two drops of methyl red. For each of the solutions write the concentration of hydrochloric acid, the color of methyl red in a strongly acidic solution, and in a basic solution. Ask students to find the pH at which a color change occurs in this indicator.

Resource Sheet 5

DISCUSSION OF ENERGY RELATIONSHIPS IN INORGANIC REACTIONS

This unit is designed to show the relationship between energy and the structure and behavior of matter. Energy shifts cause changes in structure because such shifts act as a stress which upsets the equilibrium of forces acting on matter. For this reason, concepts concerning equilibrium and energy are considered to be the unifying principles of all chemical reactions and should be emphasized throughout the unit.

The theory of chemical reactions may be introduced by teaching collision theory and the related factors which contribute to or cause upset of a state of dynamic equilibrium. Placing emphasis on the concept of equilibrium merely expands the conventional approach to include the relationship of shifts in energy and changes in the structure of matter. At this point the law of mass action should be taught only in relation to the number and frequency of collisions. Chemical equations will be used even though they are not mentioned in the outline. Free energy relationships and driving forces of chemical reactions should be introduced. It is suggested that detailed work involving an understanding of the mathematical relationships of the law of mass action, chemical reactions, and related energy changes be undertaken only with classes of high ability.

The following energy relationships and distinctions should be developed:

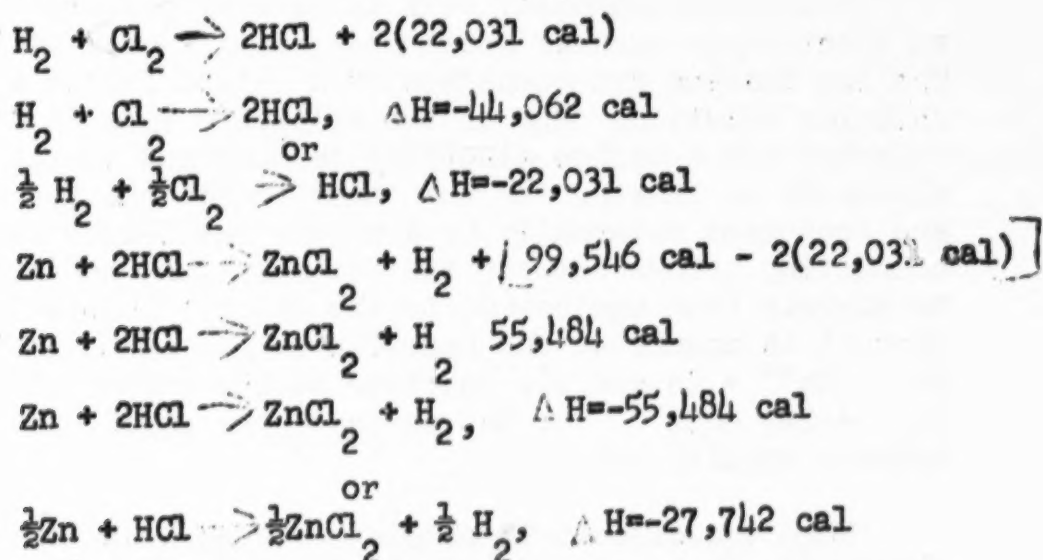
1. The relationship between bond energy and heat of reaction
2. The relationship between heat of reaction and heat of formation
3. The relationship between chemical equilibrium and exothermic and endothermic processes
4. The relationship between heat energy, free energy changes, and electrical energy in chemical reactions
5. The relationship between mass action and rate of reaction
6. The distinction between ionization potential and electrode potential

The following exposition is an attempt to show by example the above mentioned energy relationships. A direct combination type of reaction is used throughout for illustration. When two stable elements, such as zinc and chloride, are in contact with each other, they react to form zinc chloride by exchanging electrons. The reaction is exothermic because energy is emitted. This change of free energy is related to the heat of reaction and it is directly proportional to the bond energy. The bringing

together of two stable elements, each with energy in a state of equilibrium, places them under stress because the electrical fields of force of these elements interpenetrate to produce an imbalance of energy. As the zinc atom loses electrons and as the chlorine gas gains electrons, a readjustment takes place and energy is emitted. Ionically bonded and stable zinc chloride is produced and the energy of the compound is again in a state of dynamic equilibrium. The ionic bonds possess bond energy which is directly proportional to the energy released when the bonds are formed; therefore, the same amount of energy is required to break the bonds to form neutral atoms of zinc and chlorine. Bond energy is equal to the difference between the energy required to pull two electrons off an atom of zinc (ionization potential measured in electron volts) and the energy emitted as the result of electron affinity of chlorine gas plus the attraction of positive ions for negative ions (measured in electron volts).

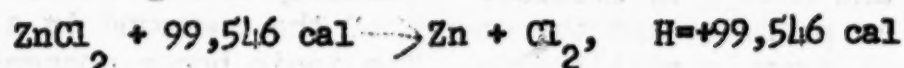
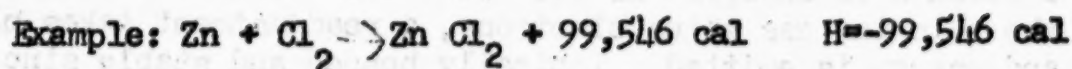
Heat of formation is a special type of heat of reaction and the two are equal only when a compound is made by direct union of elements. For example, the reaction between one mole of zinc and one mole of chlorine to produce one mole of zinc chloride releases 99,546 calories of heat. The heat of this reaction is therefore -99,546 calories and so the heat of formation of zinc chloride is also -99,546 calories/mole.

On the other hand, if one mole of zinc reacts with one mole of hydrochloric acid to produce one mole of zinc chloride, the heat of reaction is -55,484 calories even though the heat of formation of zinc chloride is -99,546 calories. This shows that heat of reaction and heat of formation do not always involve the same amount of energy. In reactions other than direct combination the heat of reaction is the difference between the heats of formation (times the number of moles in the reaction) of the reacting compounds and the heats of formation (times the number of moles in the reaction) of the compound produced. The following example illustrates one application of Hess' law. The heat of formation of HCl is -22,031 calories.



Whenever a reaction involves the formation of a bond, energy is released and whenever a reaction involves the breaking of a

bond energy is absorbed. Since exothermic reactions are the reverse of endothermic reactions, energy acts in reverse.



In the reaction between zinc and hydrochloric acid, energy is absorbed to break the bond of hydrochloric acid and energy is emitted by the formation of the zinc chloride bonds. Since zinc chloride is a more stable compound than hydrochloric acid, its total bond energy and heat of formation would be greater. The heat of reaction is the difference between the energy absorbed to break the bond of hydrochloric acid and the energy liberated by formation of the bonds of zinc chloride.

It has now been established that the reaction between zinc and chlorine, when the two elements are in contact with each other, liberates energy in the form of heat. However, if the same two elements are made to interact without contact, the released energy will be in the form of electricity. The emission of energy in any form by any chemical reaction is an exothermic process and the absorption of any form of energy by any chemical reaction is an endothermic process.

Zinc and chlorine can be made to react without contact, if an electrochemical cell is set up. Oxidation-reduction or the exchange of electrons between zinc and chlorine takes place through a conductor. The zinc atom with low ionization potential is the electron donor or reducing agent and chlorine gas possessing high chemical affinity for electrons is the electron acceptor or oxidizing agent. The conductor serves as a convenient "pathway" for the electrons which flow from a point of high electron pressure to a point of low electron pressure as the system seeks a state of dynamic equilibrium.

The electrochemical cell is made by placing a solution of an electrolyte such as sodium chloride in each of two beakers. The two beakers are connected by a U-tube filled with sodium chloride solution. One of the solutions is saturated with chlorine and a carbon electrode is immersed in it. A zinc electrode is immersed in the other beaker and the two electrodes are connected externally by a wire. The U-tube serves as a conducting bridge between the two solutions and allows the ions to migrate from one beaker to the other. Before the external circuit is completed the reaction at the zinc electrode is $\text{Zn} \rightarrow \text{Zn}^{++} + 2e$ and the reaction at the carbon electrode is $\text{Cl}_2 + 2e \rightarrow 2\text{Cl}^-$. The two parts of the system are in a state of dynamic equilibrium.

When the circuit is completed these reactions cause a difference in "concentration" of electrons. This difference results in the flow of electrons through the conductor from a point of high potential to a point of low potential or from a

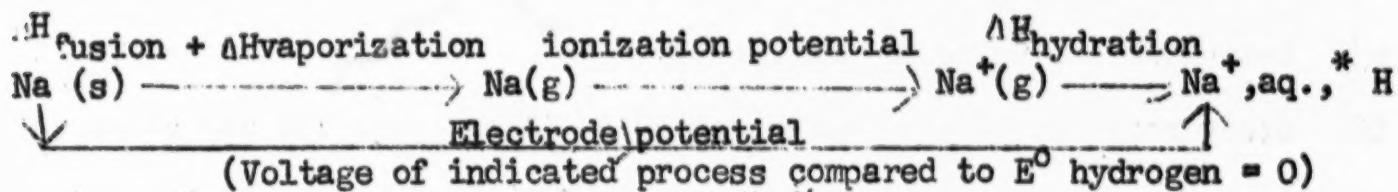
point of high "concentration" of electrons to a point of low "concentration" of electrons. The system is under stress as long as this potential difference exists. The reaction at the zinc electrode is $\text{Zn}^0 \rightleftharpoons \text{Zn}^{++} + 2e$ and the reaction at the carbon electrode is $\text{Cl}_2^0 + 2e \rightleftharpoons 2\text{Cl}^-$.

The application of the law of mass action to this reaction is as follows: If the concentration of zinc ions is increased, the reverse reaction at the zinc electrode is favored; if the concentration of chloride ions is increased, the reverse reaction at the carbon electrode is favored. Increasing concentration of either ion tends to produce a state of dynamic equilibrium at the electrode and this state may be reached if the increase in ion-concentration is great enough. At the zinc electrode, for example, an increase in zinc ion concentration reduces the activity by which zinc atoms change to zinc ions. This results in a decrease of "concentration" of electrons and of the potential on the electrode, a decrease of difference in potential, and a decrease of electron flow. The rate of the reaction slows down and the amount of liberated energy is decreased. If the ion concentration is increased excessively, equilibrium is upset and the reaction reverses itself.

The amount of energy necessary to form an aqueous ion from the atom cannot be measured experimentally for an individual electrode. All one can do experimentally is work with a whole cell. Electrode potential (volts) is the relative tendency of an element, as compared with hydrogen whose potential is defined arbitrarily as zero, to release electrons and to give up positive ions to its solution. Since the concentration of ions changes electrical potential, a standard concentration is used to compare electrode potentials or different elements. The concentration used for this purpose is one gram-ion/1000 milliliters of solution at 25°C.

Ionization potential, on the other hand, is an absolute measurement of energy (electron volt); it is the amount of energy necessary to remove electrons from an atom in the gaseous state to change the atom to an ion in the gaseous state. It is not directly related to electrode potential. Ionization potential is a component energy change of a series of energy changes involved in transforming an atom to an aqueous ion. This series of changes in energy includes heat of fusion (ΔH_f), heat of vaporization (ΔH_v), ionization potential, and heat of hydration.

Electrode potential is measured by comparing the voltage generated by the transition of solid atomic sodium to hydrated ionic sodium with that of a standard hydrogen electrode whose potential is arbitrarily set at zero. As is illustrated in the following diagram H is the same for the transition of solid atomic sodium to hydrated ionic sodium regardless of the path. This is a further application of the law of Hess.



* H for the entire process is the summation of all the energy changes taking place.

SUGGESTIONS FOR INDEPENDENT STUDY

1. Show how the degree of hydrolysis of a solution of a selected salt of a weak acid and a strong base depends on the temperature of the solution.
2. Study the rate of solution of a salt by experiment as described in Alyea, Tested Demonstrations in Chemistry, page 103, number 5-38 s.
3. Use titration techniques to determine the vitamin C content of various substances as described in Scientific Experiments in Chemistry, experiment 30.
4. Study the migration of charged particles by means of paper electrophoresis as suggested in the Journal of Chemical Education, January 1961, page 36.
5. Study the relative effectiveness of several different antacid preparations used in controlling excess stomach acid as suggested in Garrett, page 253, number 3.
6. Electroplate or use several plated metals and determine which best withstands corrosion. Explain why. See Joseph, pages 260-261 for plating suggestions.
7. Determine experimentally the pK value of an indicator.¹
8. Show that because of hydrolysis, a solution of ammonium sulfide has a lower concentration of sulfide ions than a solution of sodium sulfide of the same stoichiometric concentration.
9. Show that, compared to each other, tin (II) sulfide is basic and tin (IV) sulfide is acidic.
10. Show that it is possible, under proper conditions, for a metal that is below another in the electromotive series to form ions while the more readily oxidized metal is precipitated from solution.
11. Determine the solubility product of any slightly soluble salt and compare results to a handbook value.
12. By a procedure which requires titration, determine the CO₂ content of the air in the lungs as a function of the length of time after inhalation.
13. Practice and use the techniques of paper or column chromatography. Refer to the bibliography for some suggested references. Also see entire books devoted to the topics.
14. Study and use principles of ion exchange. A few of the many references are listed in the bibliography.
15. Determine the value of the faraday.
16. Study rhythmic banding as suggested in Alyea, page 151 and other references.
17. Form trees of lead and other metals. See Alyea, pages 89-90, and other references.

¹Suggestions 7-12 were selected from Young, Jay A., Practice in Thinking.

UNIT FIVE

ORGANIC REACTIONS

The purpose of this unit is to survey the field of organic chemistry rather than to treat any aspect of it in depth. A central emphasis on the nature of the covalent bond will relate the unit to one of the major ideas of the entire course but the subject matter content is in other respects more concrete than that of most of the other units.

The history, nature, and extent of organic chemistry can be used to introduce the unit. Detailed examination of covalent and hydrogen bonds should probably precede consideration of the hydrocarbons and their derivatives since distinctions among them are based on the saturation or unsaturation of bonds. In connection with multiple bonds, a source of confusion can be eliminated by an early and emphatic clarification of the difference between their thermal stability and their chemical stability. A multiple bond tends to resist thermal decomposition but is a highly reactive site for chemical change.

Throughout the unit I. U. C. nomenclature should be used with other names given when necessary. Empirical and molecular formulas must be taught but the use of graphic formulas should be actively encouraged since the mechanisms of organic reactions can be visualized much more readily by this method.

After consideration of the hydrocarbons and their derivatives a topic dealing with other significant organic reactions is included but should not be considered either exhaustive or restrictive. The method of treating reactions outlined in the resource sheets may be helpful to teachers but, again, is to be thought of only as a suggestion, not as the only possible approach. In connection with this section a lack of references to books at the high school level will be noted. Since this information is not usually available in such books the teacher will have to resort to extensive use of chalkboard and duplicated materials to assist students.

The final section of the unit is intended as an opportunity for interested students to investigate significant applications of organic chemistry. Such investigations might serve as a basis for subsequent student projects.

Organic Reactions

I. Introduction

- A. History of organic chemistry
- B. Nature and extent of organic chemistry

- 1. Inorganic versus organic compounds
 - 2. Divisions of organic chemistry

- C. Bonding and organic compounds

- 1. Ionic bonds
 - 2. Covalent bonds

- a. Single
 - b. Double
 - c. Triple

- 3. Hydrogen bond

II. Structure and nomenclature

A. Open chain

- 1. Saturated hydrocarbons; alkanes

- a. Homologous series

- (1) Bonding
 - (2) Nomenclature
 - (3) Isomerism
 - (4) Properties

- b. Preparation

- 2. Unsaturated hydrocarbons

- a. Alkenes
 - b. Alkynes

B. Ring structure

- 1. Saturated hydrocarbons; cycloalkanes
- 2. Unsaturated hydrocarbons; aromatics

III. Hydrocarbon derivatives

- A. General formulas
- B. Preparation

IV. Organic reactions

- A. Hydrogenation and dehydrogenation
- B. Polymerization
- C. Hydrolysis and dehydration
- D. Alkylation
- E. Cracking

V. Applications of organic chemistry

- A. Identifying and determining the structure of natural and artificial compounds
- B. Modifying natural compounds
- C. Synthesizing natural compounds
- D. Synthesizing artificial compounds for specific purposes

II. Suggested Procedures

CONTENT	TEACHING SUGGESTIONS	REFERENCES
I. Introduction A. History of organic chemistry	As an introduction to the study of organic chemistry have a student present a report on the synthesis of urea by Friedrich Wöhler and the subsequent collapse of the vital force theory. Relate this synthesis to Justus von Liebig's establishment of the empirical formula of uric acid. Demonstrate either the synthesis of urea by Wöhler's process or the reversion of the synthesis. *Send students to the library to locate information and to prepare a report on the various degradations of uric acid by Wöhler and Liebig.	Kelley <u>Organic Chemistry</u> pp. 1-2 Alyea and Dutton <u>Tested Demonstrations in Chemistry</u> p. 64
B. Nature and extent of organic chemistry 1. Inorganic versus organic compounds	Display some organic and inorganic compounds. Demonstrate and enumerate for the class points of difference between inorganic and organic compounds and their reactions. Include color, melting point, solubility, isomerism, ionization, decomposition, reaction speed, etc. After class discussion have the students summarize the differences in a table such as the following:	Kelley <u>Op. cit.</u> p. 3 Dull, et al. <u>Modern Chemistry</u> p. 230

CONTENT	TEACHING SUGGESTIONS	REFERENCES						
	A COMPARISON OF INORGANIC AND ORGANIC COMPOUNDS AND REACTIONS <table border="1" data-bbox="455 766 802 1717"> <thead> <tr> <th data-bbox="455 1370 559 1717">Characteristic</th><th data-bbox="455 1072 559 1370">Inorganic</th><th data-bbox="455 766 559 1072">Organic</th></tr> </thead> <tbody> <tr> <td data-bbox="559 1370 802 1717"></td><td data-bbox="559 1072 802 1370"></td><td data-bbox="559 766 802 1072"></td></tr> </tbody> </table> Have students study the position of carbon on the periodic table, its detailed electron configuration, and its properties. Define the domain of organic chemistry explaining that a few compounds of carbon are included in the study of inorganic chemistry. Ask students to estimate the total number of organic and inorganic compounds. Compare their estimates with actual numbers.	Characteristic	Inorganic	Organic				Garrett, et al. Chemistry pp. 383-384, 396 Dull, et al. Op. cit. pp. 204-205 Kelley Op. cit. p. 2 Garrett, et al. Op. cit. p. 448
Characteristic	Inorganic	Organic						

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Divisions of organic chemistry C. Bonding in organic compounds 1. Ionic bonds 2. Covalent bonds a. Single	Now that students have an appreciation of the immensity of the field of organic chemistry show them that the study of organic compounds is simplified by classifying them into typical groups. Prepare for the students a dittoed sheet illustrating the typical classification of the hydrocarbons and their derivatives. Discuss the usefulness of flow charts. Ionic bonding is relatively unimportant in organic chemistry but the topic should be reviewed. The purpose of this section is not to teach detailed information about bonding but rather to extend the concepts learned earlier, emphasizing that the carbon atom is tetravalent and the hydrogen atom is monovalent. Write the molecular formula for methane on the board and ask the class to draw the structure with electron dots. Teach students to write graphic formulas, representing each covalent bond by a line. Construct a model of methane with tinker toys or molecular models. In classes of high ability explain that the binding force is exerted in a definite direction and that it is possible to speak of directed valences and bond angles.	Resource Sheet 1 Kelley Op. cit. p. 16 Ibid. p. 17 Ibid. p. 17 Joseph, et al. A Sourcebook for the Physical Sciences pp. 267-268

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	*Teach the class the directional characteristics of covalent bonds especially sp^3 (tetragonal) and p^3 (pyramidal) bond types. Replace one of the hydrogen atoms in the methane model with a carbon atom. Explain to the class that one of the reasons for the existence of so many organic compounds is that carbon atoms can bond covalently to one another. Now attach enough hydrogen atoms to saturate the valence of the carbon atom. Impress upon the class that carbon is tetravalent and all four bonds must be satisfied. Ask students to draw electron dot formulas and graphic formulas for other selected saturated hydrocarbons. Make models of the molecules and use them to show rotation of atoms about a single bond axis. Explain that this is possible because the distribution of electrons is radially symmetrical. Remove a hydrogen atom from each carbon atom in the molecular model of ethane and attach the carbon atoms by a double bond. Have the class draw the electron dot and graphic formulas for ethene. Show that there is no rotation about multiple bonds. Recall the structure of the nitrogen molecule and construct ethyne from ethene. Study interatomic distances between	Eichinger The Electron Chart p. 31 Bradbury, et al. Chemistry and You pp. 465-466 Kelley Op. cit. p. 23 Garrett, et al. Op. cit. pp. 461-462 Kelley Op. cit. p. 48 Garrett, et al. Op. cit. p. 361
b. Double		
c. Triple		

CONTENT	TEACHING SUGGESTIONS	REFERENCES
3. Hydrogen bonds II. Structure and nomenclature A. Open chain 1. Saturated hydrocarbons; alkanes a. Homologous series	singly, doubly, and triply bonded carbon atoms; bond energies; activity; and polarity. The important idea to present here is that multiple bonds have greater thermal stability than single bonds but are chemically more reactive. Ask students to recall the discussion of the hydrogen bond from Unit One. Develop the concept using the line of reasoning from Hiller and Herber. Organic chemists find evidence of this type of bond in a large number of compounds having the O-H and N-H linkage. As an example cite the two compounds, dimethyl ether and ethanol, each with the same empirical formula; ethanol, having an O-H bond, boils at a temperature over 100°C higher than the ether. Ask the class to explain why. Draw on the chalkboard the graphic formulas for the first five normal members of the alkane series. Ask the class to add the next five members. Point out the obvious similarities: 1. All members are saturated. 2. All members are open chain. 3. Members of the series differ in composition by the increment CH_2.	Kelley <u>Op. cit.</u> pp. 18, 20-23 Andrews and Kokes <u>University Chemistry</u> <u>Vol. II</u> pp. 22-26 Hiller and Herber <u>Principles of Chemistry</u> pp. 88-90 Carleton, et al. <u>Chemistry Activities</u> pp. 219-224 Garrett, et al. <u>Op. cit.</u> p. 463

CONTENT	TEACHING SUGGESTIONS	REFERENCES
(1) Bonding	Ask students to write molecular, graphic, and structural formulas for members of the alkanes.	
(2) Nomenclature	Write on the board the names and molecular formulas of the first ten members of the alkanes. Call attention to the -ane ending. Explain that all members of the alkanes are singly bonded (saturated), a fact indicated by the -ane ending. Tell the class that the Latin and Greek prefixes are used not only for the alkanes but for many organic series. Have them memorize the first ten prefixes. Use the I. U. C. system of nomenclature.	Joseph, et al. Op. cit. p. 270 Kelley Op. cit. p. 34 Garrett, et al. Op. cit. pp. i-iii
(3) Isomerism	After students have mastered the basic nomenclature of the alkanes introduce the alkyl groups and their names. Begin the study of isomerism by distributing to various groups of students 6 carbon balls, 14 hydrogen balls, and sticks for bonds. Ask each group to assemble one molecule using all of the atoms. If they do this independently someone will probably come up with an isomeric form. Define isomerism. Ask students to write all of the graphic formulas for isomers of heptane. Teach them the I. U. C. system for naming branched hydrocarbons. Some students will incorrectly assume that compounds like C-C-C-C-C-C and C-C-C-C-C-C are different isomers. Make a model of 2-methylhexane and show the class that the molecule can be turned over and around without altering its structure. Discuss the spatial configuration of organic molecules.	Kelley Op. cit. pp. 33-34, 40 Garrett, et al. Op. cit. pp. 463-464 Kelley Op. cit. p. 34

CONTENT	TEACHING SUGGESTIONS	REFERENCES
(4) Properties b. Preparation	Practice formula writing and nomenclature by having the class write formulas and name possible isomers of octane or nonane. Point out the limitations of molecular formulas and stress the use of graphic and structural formulas. List on the board every other one of the first twenty alkanes. Add their melting and boiling points, molecular formulas, and molecular weights. Once again note that successive members differ in composition by the increment CH_2 and with the class develop the general formula $\text{C}_n\text{H}_{2n+2}$. Have each student plot the boiling point ($^{\circ}\text{C}$) against the molecular weights of all hydrocarbons in the list. Predict the boiling points of those omitted and check the results in a handbook. Explain the trends in physical states within a series in terms of intermolecular forces. Teach the class some general methods for preparing alkanes including: 1. Hydrolysis of a Grignard reagent (length of carbon chain remains unchanged) 2. Reduction of an alkyl halide (the carbon chain lengthens) 3. Fusion method (the carbon chain becomes shorter) Demonstrate the preparation of methane by the fusion method.	Kelley <u>Op. cit.</u> p. 35 Hodgman (ed.) <u>Handbook of Chemistry and Physics</u> Kelley <u>Op. cit.</u> pp. 41-42 Markham and Reilley <u>A Laboratory Manual for General Chemistry</u> pp. 375-378

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Unsaturated hydrocarbons a. Alkenes	Bonding, nomenclature, isomers, and properties for each of these other homologous series should be discussed. Review the concept of the double bond developed earlier. Establish the fact that the double bond is thermally stronger than a single covalent bond but because it is unsaturated it is chemically more reactive. In classes of high ability develop a discussion around the organization and material in Fieser and Fieser. Help the students work out the nomenclature for simple alkenes and teach them the conventions for naming compounds so as to indicate the position of the double bond. Select an alkene and ask the class to write graphic formulas and name isomers of the compounds. Construct a model of an alkene and show the class that there is no rotation about the double bond. In classes of high ability compare the interatomic distances between carbon atoms in single and double bonds with their bond energies. Discuss the general physical properties of the alkenes, and develop the general formula C_nH_{2n}.	Kelley Op. cit. pp. 17, 50-51 Fieser and Fieser Introduction to <u>Organic Chemistry</u> pp. 45-48 Kelley Op. cit. pp. 49-50 Ibid. pp. 21-22 Fieser and Fieser Op. cit. p. 38

CONTENT	TEACHING SUGGESTIONS	REFERENCES
b. Alkynes	Alkenes may be prepared by introducing a double bond into a saturated compound. Teach the class the three methods that introduce the double bond by virtue of the removal of two units from adjacent carbon atoms in a saturated compound: 1. The action of alcoholic KOH on an alkyl halide 2. The action of zinc on a dihalogen derivative of an alkane (when the two x's are on adjacent carbon atoms) In classes of high ability teach alkadienes. 3. The action of a dehydrating agent on an alcohol Plan a laboratory exercise so that the class can prepare and study the properties of ethene. Ask the class to predict the stability of the alkenes from their knowledge of the alkenes and to check the predictions by using the Baeyer test for the double bond. Review the triple covalent bond. Study ethyne as a typical alkyne. Ask the students to predict the stability, bond energies, and activity of alkynes. Discuss isomerism and nomenclature generally. Develop the general formula C_nH_{2n-2}. Have the students prepare ethyne and observe its properties. Use the addition of bromine to ethyne to illustrate its unsaturation.	Kelley Op. cit. pp. 51-52 Joseph, et al. Op. cit. pp. 276-277 Kelley Op. cit. pp. 74-82 Bradbury, et al. Op. cit. p. 470 Markham and Reilley Op. cit. pp. 375-378

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Ring structure 1. Saturated hydrocarbons; cycloalkanes 2. Unsaturated hydrocarbons	Make a molecular model of pentane. Rotate the model around the C-C bonds until the terminal methyl groups are brought close together. *Introduce the Baeyer strain theory to classes of high ability. Have the class write graphic formulas for cyclopropane through cyclohexane and predict relative stability in terms of bond distortion. *Have a student report on Kekulé's proposed structure of the benzene ring. In classes of high ability show how the concept of resonance hybridization accounts for the stability of this structure. By performing the indicated demonstration show that the reactions of benzene and its homologs more closely resemble those of the alkanes rather than those of unsaturated hydrocarbons. Teach I. U. C. nomenclature for the aromatic hydrocarbons by showing the possible positions of the substituents on a benzene ring. The convention of using ortho-, para-, and meta- should be mentioned since it appears in the literature. Use several different isomers to give the students practice in naming these compounds.	Kelley Op. cit. pp. 63-64, 461 Fieser and Fieser Op. cit. pp. 35, 235-240 Andrews and Kokes Op. cit. pp. 27-30 Kelley Op. cit. pp. 476-478 Joseph, et al. Op. cit. p. 279 Kelley Op. cit. pp. 481-483

CONTENT	TEACHING SUGGESTIONS	REFERENCES															
III. Hydrocarbon derivatives A. General formulas	Ask several students to prepare an exhibit of familiar products which are derivatives of the aromatics. *Discuss anthracene and naphthalene as examples of condensed nuclei. Introduce hydrocarbon derivatives by reviewing briefly the alkyl and aryl radicals. Show that many compounds consist of these residues plus other radicals or functional groups. The following type of table is suggested to summarize the information: H. RO-CARBON DERIVATIVES <table border="1"> <thead> <tr> <th>Name</th><th>Functional Group</th><th>General Formula</th></tr> </thead> <tbody> <tr> <td>Alkyl Halides</td><td>-X</td><td>RX</td></tr> <tr> <td>Alcohol Primary</td><td>-C-H</td><td>ROH</td></tr> <tr> <td>Ether</td><td>-O-</td><td>ROR</td></tr> <tr> <td>Etc.</td><td></td><td></td></tr> </tbody> </table>	Name	Functional Group	General Formula	Alkyl Halides	-X	RX	Alcohol Primary	-C-H	ROH	Ether	-O-	ROR	Etc.			Ibid. pp. 605-608, 612-616 Dull, et al. Op. cit. pp. 622-635 Bradbury, et al. Op. cit. pp. 489-512 Garrett, et al. Op. cit. pp. 475-491 Sienko and Plane Chemistry pp. 546-554 Markham and Smith General Chemistry pp. 567-575
Name	Functional Group	General Formula															
Alkyl Halides	-X	RX															
Alcohol Primary	-C-H	ROH															
Ether	-O-	ROR															
Etc.																	

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Preparation	Drill students on nomenclature of hydrocarbon derivatives. Give the method of preparation for each of the derivatives dealt with in the preceding chart. Using Resource Sheet 2 show students how propane can be prepared from carbon by the indicated series of reactions. Students should learn to show the mechanism of organic reactions by using graphic formulas in the equations. Use graphic equations to show the substitution reaction by which a primary alcohol is formed from a hydrocarbon. See Resource Sheet 2. Use Resource Sheet 2 as a guide to the series of transformation reactions by which other important hydrocarbon derivatives can be prepared. This series of reactions is only one of several possible means of preparing the compounds. In the laboratory have students oxidize and dehydrate primary and secondary alcohols to form aldehydes, ketones, and ethers. Students should now be able to predict the action of the oxidation and dehydration of aldehydes to form organic acids. Illustrate this transformation with graphic formulas.	See References for A. General formulas. Resource Sheet 2 Bradbury, et al. Op. cit. <u>467</u>, 489 Resource Sheet 2 Markham and Reilley Op. cit. <u>383-386</u> Garrett, et al. Op. cit. <u>482-484</u> Bradbury, et al. Op. cit. <u>497-501</u>

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	Use graphic formulas to show the mechanism of esterification. Have students observe these reactions in a laboratory period. *Ask a student to present a demonstration illustrating differences between inorganic and organic acids. Students should select several hydrocarbons of the methane series and carry them through the transformation reactions in Resource Sheet 2. Follow the study of esters with a discussion of saponification. Schedule a laboratory period after the discussion of the formation and properties of soaps. Amines, amino acids, organic salts, and fats are formed by the type of reactions shown on Resource Sheet 2. Teach nomenclature, preparation, and graphic representations by means of student reports and investigations. The formation of monosaccharides and disaccharides should be familiar to the student. Properties and related reactions can be covered by student reports. Include reports on polysaccharides.	Joseph, et al. Op. cit. pp. 287-288 Garrett, et al. Op. cit. pp. 484-486 Ibid. pp. 486-487 Joseph, et al. Op. cit. pp. 289-290 Bradbury, et al. Op. cit. pp. 512-519 Markham and Smith Op. cit. pp. 535, 578-582

CONTENT	TEACHING SUGGESTIONS	REFERENCES
IV. Selected reactions A. Hydrogenation and dehydrogenation B. Polymerization C. Hydrolysis and dehydration D. Alkylation E. Cracking	It is important that the teacher emphasize that the reactions used in this section are not the only possible methods for the formation of the compounds studied. Conduct numerous drills on the recognition and nomenclature of the compounds. Enumerate various types of organic reactions not previously dealt with in this unit. Give some examples of processes utilizing the reactions and have students look up further examples. Use the hydrogenation of polyunsaturated fats to illustrate this reaction and the preparation of butadiene as the reverse process. Describe the making of polyethylene as an example of polymerization. Show how polysaccharides are broken down into monosaccharides by hydrolysis and how monosaccharides combine to form disaccharides by splitting out a molecule of water. Explain how alkylation and cracking are applied in the manufacture of gasoline.	Kelley <u>Op. cit.</u> <u>p. 180</u> <u>Ibid.</u> <u>p. 55</u> <u>Ibid.</u> <u>p. 425</u> <u>Ibid.</u> <u>pp. 63,88</u> Bradbury, et al. <u>Op. cit.</u> <u>p. 475</u> Garrett, et al. <u>Op. cit.</u> <u>pp. 452-454</u>

CONTENT	TEACHING SUGGESTIONS	REFERENCES
V. Applications of organic chemistry A. Identifying and determining the structure of natural and artificial compounds B. Modifying natural compounds	The basic objectives of research and industry in organic chemistry are given as sub-topics in the outline for topic V. Any of these sub-topics will serve to bring together the major concepts in the unit as they are applied in current developments in organic chemistry. Have students select one or two areas of particular interest and present them through student reports. The structure of macromolecules is of fundamental importance to the biologist and chemist. Investigate the structure, linkage, and classification of simple, conjugated, and derived proteins. Individual students can report on suggested articles from the <u>Scientific American</u>: "Nucleic Acids," September 1957 "How Giant Molecules Are Measured," September 1957 "Proteins," September 1957 "Nucleic Acids and Proteins," December 1959 "How Is a Protein Made?," September 1953 "Giant Molecules in Cells and Tissues," September 1957 "The Chemical Structure of Proteins," February 1961 "The Insulin Molecule," May 1955 The control of body metabolism involves the study of macromolecules in fats, proteins, and carbohydrates. Assign suggested topics for individual reports from either Harrison or the <u>Scientific American</u>: "Steroids," January 1955 "Biological Oxidation," July 1958 "The Action of Insulin," May 1958 "ATP," April 1953	Harrison A Guide-book to <u>Biochemistry</u> pp. 77-138

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A. Books

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Harrison, Kenneth. A Guide-Book to Biochemistry. Cambridge, England: Cambridge University Press. 1959

Joseph, A., Brandwein, P., Morholt E., Pollack, H., and Castka, J. A Sourcebook for the Physical Sciences. New York: Harcourt, Brace and World, Inc. 1961

Kelley, Louise. Organic Chemistry. New York: McGraw-Hill Book Company, Inc. 1957

B. Laboratory Manuals

Alyea, Hubert N. and Dutton, Frederic B. Tested Demonstrations in Chemistry. Easton, Pennsylvania: Division of Chemical Education of the American Chemical Society. 1960

Carleton, R., Woodburn, J. and Elder, T. Chemistry Activities. New York: J.B. Lippincott Company. 1954

C. Periodicals

Ayres, Eugene, "The Fuel Situation," Scientific American 194: 43-49, October 1956

Carries a discussion of the present fuel situation with possible solutions to pressing problems.

Beecher, Henry K., "Anesthesia," Scientific American 196:70-83, January 1957

Discusses pain relieving drugs and some of their effects.

Bridgman, P.W., "Synthetic Diamonds," Scientific American 181:32-39, November 1949

Discusses methods for the production of synthetic diamonds from graphite.

Crick, F.H.C., "Nucleic Acids," Scientific American 197:188-200, September 1957

Discusses the latest theory and structure of DNA and RNA.

Debye, Peter J.W., "How Giant Molecules Are Measured," Scientific American 197:90-97, September 1957

Discusses the determination of weight and degree to which molecules are folded.

Doty, Paul, "Proteins," Scientific American 197:173-187, September 1957

Describes proteins which are giant molecules built from amino acids with peptide linkage.

Fieser, Louis F., "Steroids," Scientific American 192:52-61, January 1955

Tells the story of sterioids, one of the great epics of chemistry, and discusses the sex hormones, some of the vitamins, plant sterols, and the adrenal cortical hormones.

Fisher, Harry L., "Rubber," Scientific American 195:74-88, November 1956

Describes the rubber polymer and the reason for its interest to the chemist.

Green, David E., "Biological Oxidation," Scientific American 199:56-66, July 1958

Discusses chemical reactions which take place in minute particles called mitochondria during the oxidation of carbohydrates and and fats.

_____, "The Synthesis of Fat," Scientific American 202:46-51, February 1960

Describes the synthetic process for the synthesis of fat.

Hoagland, Mahlon, "Nucleic Acids and Proteins," Scientific American 201:55-62, December 1959

Tells about a major gap in the knowledge of protein synthesis.

Levine, Rachmiel and Goldstein, M.S., "The Action of Insulin," Scientific American 198:99-109, May 1958

Discusses recent experiments which indicate that insulin is present during the passage of sugar through the walls of certain cells.

Linderstrom-Lang, K.V., "How Is a Protein Made?" Scientific American 189:100-107, September 1953

Tells that giant protein molecules are varieties of twenty-two amino acids.

Mark, Herman F., "Giant Molecules," Scientific American 197:80-89, September 1957

Surveys high-polymer chemistry.

Natta, Giulio, "How Giant Molecules Are Made," Scientific American 197:98-119, September 1957

Describes the effect of catalysis on orientation of monomers.

Oster, Gerald, "Polyethylene," Scientific American 197:139-155, September 1957

Discusses the most common polymer of ethylene.

Schmitt, Francis O., "Giant Molecules in Cells and Tissues," Scientific American 197:204-216, September 1957

Explains the organization of proteins and nucleic acid molecules in protoplasm.

Stein, William H. and Moore, Stanford, "The Chemical Structure of Proteins," Scientific American 204:81-96, February 1961

Describes the atom-by-atom structural formulas of three proteins.

Stumpf, Paul K., "ATP," Scientific American 188:84-92, April 1953

Treats adenosine triphosphate, the substance that provides energy for muscle contraction.

Thompson, E.O.P., "The Insulin Molecule," Scientific American 192:36-41, May 1955

Describes the chemical structure of the insulin molecule.

Tobolsky, Arthur V., "The Mechanical Properties of Polymers," Scientific American 197:120-138, September 1957

Explains the nature of texture of polymers in terms of structure.

Williams, Simon, "Synthetic Fibers," Scientific American 185:37-45, July 1951

Discusses numerous synthetic fibers, their preparation, and properties.

Yahraes, H., "The Arrival of Acetylene," Scientific American 180:16-22, January 1949

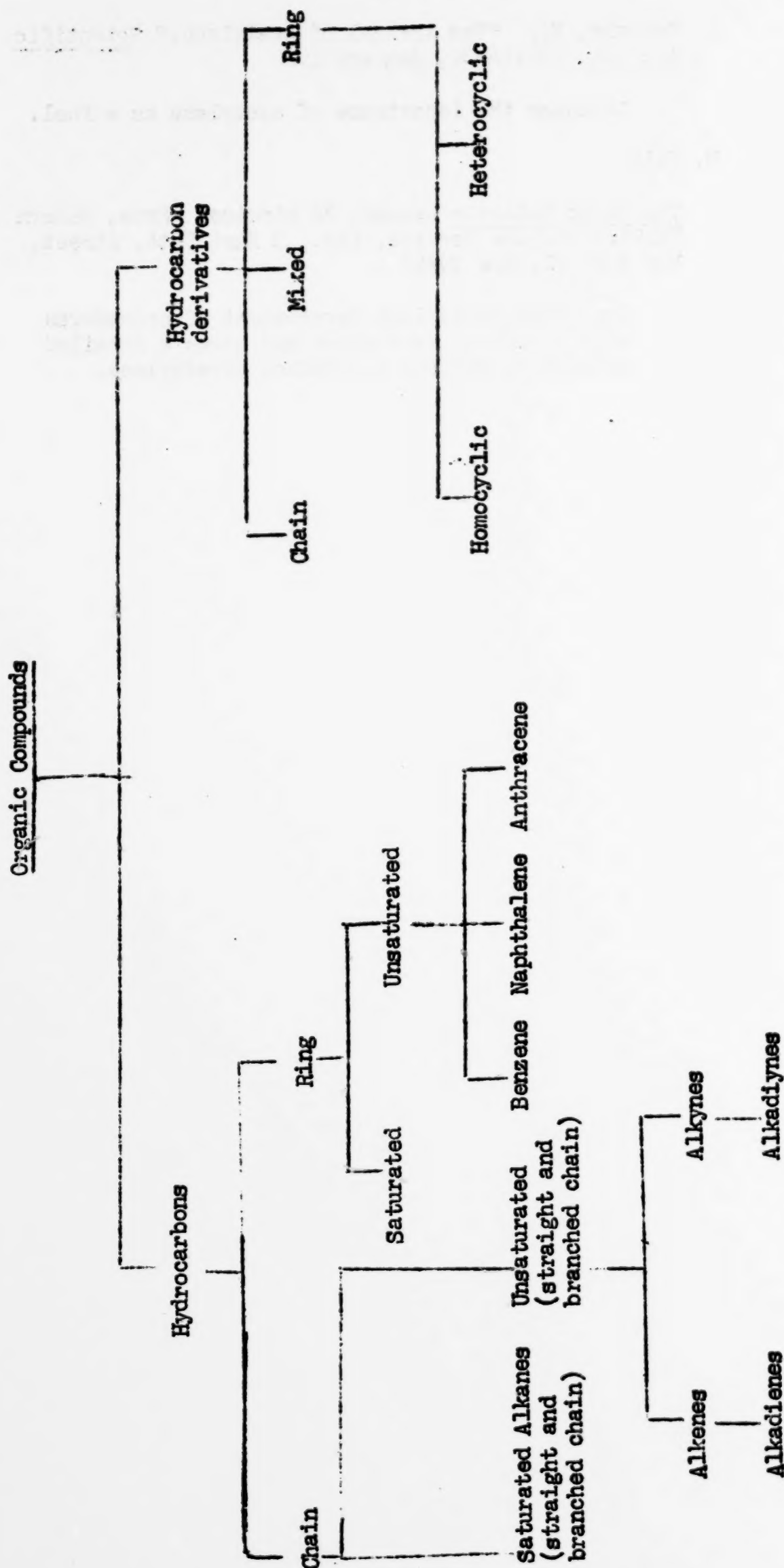
Stresses the importance of acetylene as a fuel.

D. Film

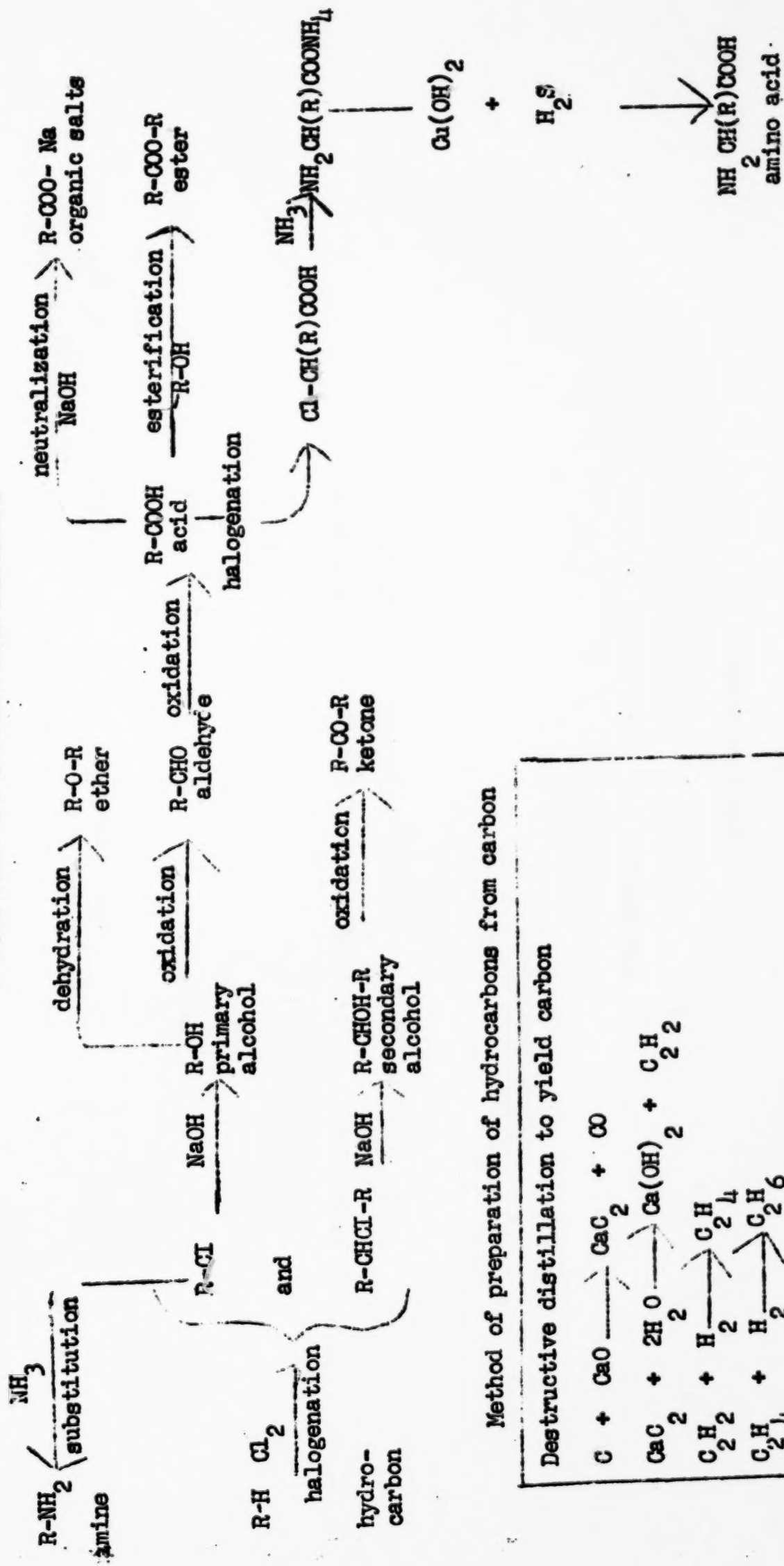
The Magic Molecule (sound, 26 minutes. Free, Modern Talking Picture Service, Inc., 3 East 54th. Street, New York 22, New York)

Describes historical development of procedures used in making synthetics and gives a detailed account of efforts to produce polyethylene.

CLASSIFICATION OF ORGANIC COMPOUNDS

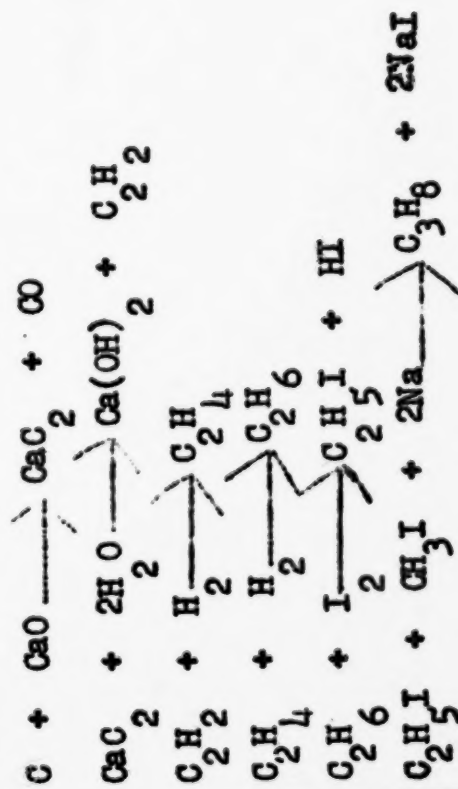


CONDENSATION AND SUBSTITUTION REACTIONS



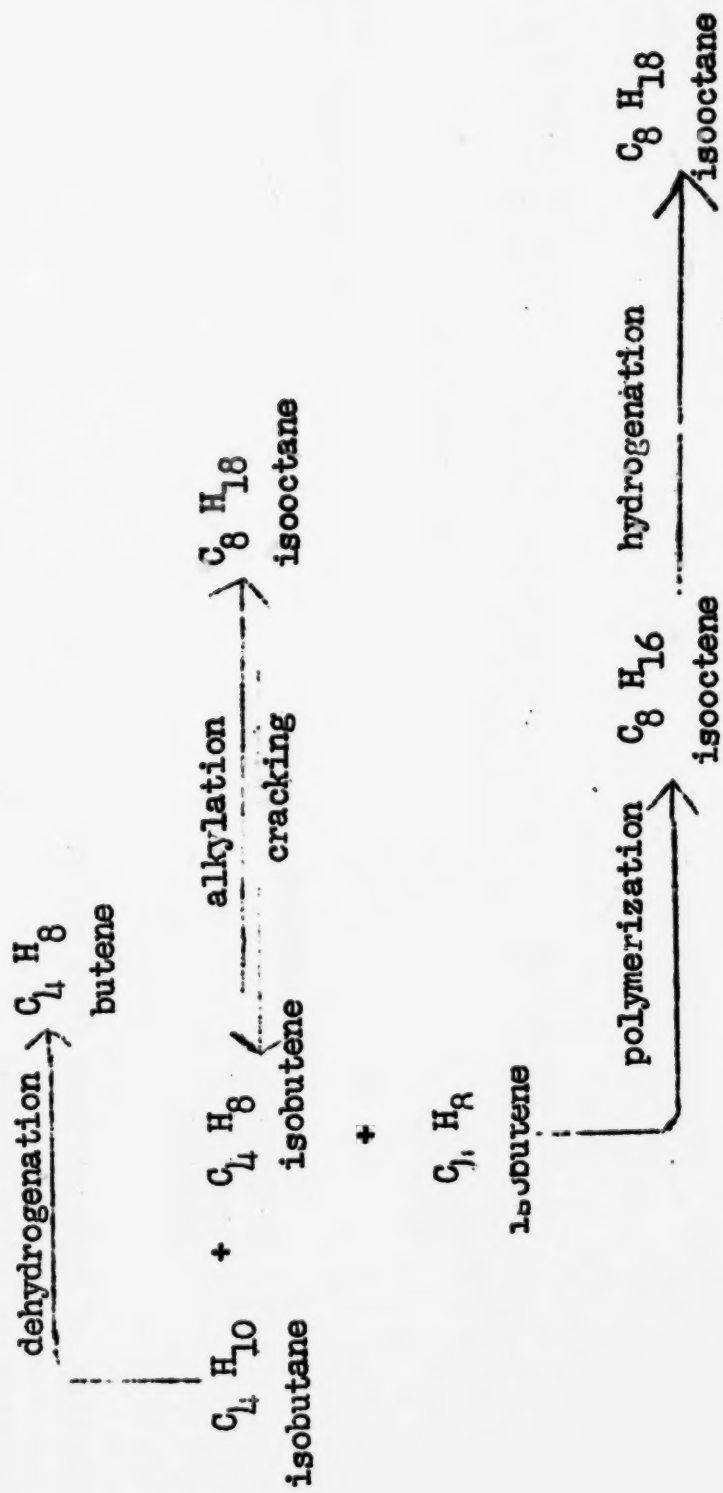
Method of preparation of hydrocarbons from carbon

Destructive distillation to yield carbon



Resource Sheet 3

CONDENSATION AND SUBSTITUTION REACTIONS



Resource Sheet 4

SUGGESTIONS FOR INDEPENDENT STUDY

1. The Journal of Chemical Education beginning in January, 1961, features a section called "Research Ideas for Young Chemists." The following items or those from more recent issues could be used as individual student projects:

"Castor Oil as a Starting Material for Laboratory Preparations,"
March, 1961

"Continuous Reactors for Preparing Organic Chemicals,"
January 1961

"The Grignard Reagent Reaches the Freshman," July 1961

"Simple Method for the Preparation of Tertiary Amines," June 1961

"Friedel-Crafts Reaction in Elementary Organic Laboratories,"
June 1961

2. Additional references that could be used as a basis for student projects are listed below:

"The Realm of Carbon," Carleton, et al. Chemistry Activities.
page 218

"Preparation of Plastics," Joseph, et al. A Sourcebook for the Physical Sciences. Exp. 14.5

"Synthesis of Aspirin," Markham and Reilley. A Laboratory Manual for General Chemistry. Exp. 79

"Preparation of Dyes, Perfumes, Polymers," Markham and Reilley.
A Laboratory Manual for General Chemistry. Exp. 78

"Preparation of DDT," Scientific Experiments in Chemistry Exp. 31

"Preparation of Rayon," Markham and Reilley. A Laboratory Manual for General Chemistry. Exp. 80

"Phenol-formaldehyde Plastic," Alyea and Dutton. Tested Demonstrations in Chemistry

3. Partially fill a large strong bottle with swamp water and partly decayed leaves. Let this stand for several weeks at room temperature. Identify the gas produced. Prepare a report on recent developments on finding petroleum deposits.
4. Several states require drivers suspected of operating their cars while under the influence of intoxicating beverages to submit to a test to determine the alcoholic content of their breath or blood. Find out how these tests are made and how accurate they are.

UNIT SIX

NUCLEAR REACTIONS

I. Scope of the Unit

The final unit in the chemistry course provides an opportunity to deal with nuclear reactions and to compare them with the chemical reactions which have been considered up to this time. Because of the importance of nuclear energy and the many problems connected with it, it seems appropriate to give more emphasis to applications than for earlier units and to include some discussion of the implications of nuclear developments such as those related to genetic and somatic effects of fallout. In all such discussions, however, teachers should guide students to reason from the best available data and should avoid imposing their social and political views on students.

Many scientists have contributed to our present knowledge of nuclear energy. The historical development should be used whenever appropriate in the unit to show how each discovery stimulates research leading to other discoveries.

A consideration of mass defect and the belt of stability can serve as central ideas in the discussion of theories concerning the structure of the nucleus. One of the three disintegration series should be used to aid the students in understanding the phenomenon of natural disintegration and the concept of half-life. The products of the disintegration of some nuclei can be predicted by considering the relationship of the nuclei to the belt of stability. A comparison of energy changes in chemical and nuclear reactions and a study of several different types of nuclear reactions should be made.

While nearly all of the reactions considered in the entire course can be interpreted in terms of three fundamental particles, the students should be introduced to some of the current theories about other subnuclear particles. High ability students may consider these in some detail. A study of the operating principles of the equipment used to detect radioactive particles and rays, to bombard nuclei, to cause transmutations, and to separate uranium isotopes should be made. The unit concludes with a consideration of practical applications of nuclear energy and problems attendant upon its use.

Nuclear Reactions

- I. Historical development
- II. Natural radioactivity
 - A. Binding energy and mass defect
 - B. Belt of stability
 - C. Types of natural radiation
 - 1. Alpha
 - 2. Beta
 - 3. Gamma
 - D. Half-life
 - E. Disintegration series
- III. Types of reactions
 - A. Transmutations involving small particles
 - B. Fission reactions
 - C. Fusion reactions
- IV. Subnuclear particles
- V. Instrumentation
 - A. Detecting devices
 - 1. Electroscope
 - 2. Geiger counter
 - 3. Cloud and bubble chambers
 - 4. Spinhartoscope and photographic film
 - B. Bombarding devices
 - 1. Accelerators
 - 2. Reactors
 - C. Separating devices
 - 1. Gaseous diffusion
 - 2. Electromagnetic
 - 3. Centrifugal
 - 4. Thermal diffusion
- VI. Uses of radioactive isotopes
 - A. Industrial uses
 - B. Biological uses
- VII. Problems
 - A. Biological effects of radiation
 - B. Contamination and clean-up
 - 1. Fallout
 - 2. Handling of radioactive materials
 - 3. Disposal of radioactive wastes

II. Suggested Procedures

CONTENT	TEACHING SUGGESTIONS	REFERENCES
I. Historical development II. Natural radioactivity A. Binding energy and mass defect	Have the students listen to the recording, "The Lost Key," which describes the work of Roentgen. Have a student report on the way in which the discovery of x-rays by Roentgen led to the discovery of radioactivity by Becquerel and to the discovery of radium and polonium by the Curies. See <u>Great Experiments in Physics</u> for the original accounts of the experiments of Roentgen and Becquerel. Use the helium nucleus as an example to show that the sum of the masses of the nucleons (protons and neutrons) does not necessarily equal the mass of the nucleus. This difference in mass is converted to energy which is called binding energy. Using the graph in Sienko and Plane have the students determine which section of the line represents elements which have the highest binding energies per particle and are thus the most stable.	Westinghouse Electric Corporation "The Lost Key" Romer <u>The Restless Atom</u> pp. 15-38 Shamos (ed.) <u>Great Experiments in Physics</u> pp. 198-215 Dull, et al. <u>Modern Chemistry</u> pp. 552-555 Sienko and Plane <u>Chemistry</u> pp. 574-576 Dull, et al. <u>Modern Physics</u> pp. 144-146, 156-157

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Belt of stability	Have the students calculate the difference between the number of neutrons and the number of protons in the nuclei of the halogens. Point out the role of the neutron in nuclear stability by having the class compare these differences and note that the more protons there are in a nucleus, the more neutrons are needed per proton for stability. Have students explain how this is indicated in the graph of stable nuclei in Sienko and Plane or on Resource Sheet 1. Point out to the students that nuclei which are not in this belt of stability are radioactive. Use the opaque projector to present the chart of the stable isotopes from Semat, page 373. Ask students to examine the graph and to note the relative frequencies with which nuclei containing an even number of protons and an even number of neutrons, or an even number of protons and an odd number of neutrons and vice versa, or an odd number of protons and an odd number of neutrons occur. Refer to Glasstone for a complete tabulation of the stable nuclei. Discuss possible models which account for the degree of stability of the doubly-even, even-odd, and doubly-odd nuclei.	Sienko and Plane <u>Op. cit.</u> pp. 567-569 Resource Sheet 1 Dull, et al. <u>Modern Chemistry</u> pp. 562-563 Dull, et al. <u>Modern Physics</u> pp. 156-157 Glasstone <u>Sourcebook on Atomic Energy</u> pp. 359-363 Semat <u>Introduction to Atomic and Nuclear Physics</u> pp. 372-374 Heisenberg <u>Nuclear Physics</u> pp. 103-112

CONTENT	TEACHING SUGGESTIONS	REFERENCES
E. Disintegration series	graphs and ask students to explain why ten half-life periods is the time suggested for storing radioactive wastes of high intensity. Have a student report on the work of Dr. Willard F. Libby, Nobel Prize winner for his method of determining the age of geological specimens by measuring their natural radioactivity. Interested students can investigate the work of other researchers in this area. Use uranium, thorium, or actinium decay as an example of a disintegration series. Teach students to write nuclear equations showing each step in one of the disintegration series. Have the students make a graph for the series as in Markham and Smith and identify several examples of isotopes. To point up variations in half-life, ask them to indicate the isotope having the shortest half-life and the one having the longest half-life. Define isobars and have the students pick out several examples from the series.	<u>Bulletin of the Atomic Scientists</u> Vol. 12, No. 9 p. 280 <u>Science</u> Vol. 128, No. 3332 pp. 472-473 <u>Science</u> Vol. 126, No. 3279 pp. 908-919 <u>National Geographic Magazine</u> Vol. 114, No. 2 pp. 234-255 Dull, et al. <u>Modern Chemistry</u> pp. 556-558 Markham and Smith <u>Op. cit.</u> pp. 540-542 Garrett, et al. <u>Op. cit.</u> p. 416

CONTENT	TEACHING SUGGESTIONS	REFERENCES
III. Types of reactions A. Transmutations involving small particles	Point out to the students that nuclei which are not in the belt of stability are radioactive and undergo reactions which will bring them closer to this belt. See reference in Sienko and Plane. Explain that the nuclei for the uranium, thorium, and actinium series lie in Section III the chart on Resource Sheet 1. Consequently, they lose particles in a number of steps in order to reach stability. Have students note that isotopes shown in Section I on Resource Sheet 1 have too high a neutron-proton ratio and in Section II have too low a neutron-proton ratio. Discuss the methods by which unstable isotopes reach a stable state. Be sure to include reactions involving K capture and positron emission. Show the filmstrip "Nuclear Energy" as an introduction to the study of artificial transmutations. Write on the board several examples of artificial transmutations. Be sure to include the first artificial transmutation by Rutherford in 1919 and the reaction by Cockcroft and Walton which provided a quantitative verification of Einstein's relationship. Have the students calculate the difference in mass between reactants and products for the latter reaction. Use the equation $E = mc^2$ to calculate the energy produced in	Glasstone <u>Op. cit.</u> pp. 132-137 Pauling <u>College Chemistry</u> pp. 646-650 Sienko and Plane <u>Op. cit.</u> (text) p. 572 Resource Sheet 1 Resource Sheet 1 Sienko and Plane <u>Op. cit.</u> pp. 568-572 McGraw-Hill Filmstrip "Nuclear Energy" Garrett, et al. <u>Op. cit.</u> pp. 417, 434-435 Glasstone <u>Op. cit.</u> pp. 86-88, 243-245

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	this reaction, assuming complete reaction between one mole of lithium and one mole of hydrogen. Express the energy in ergs, the mass in grams, and the velocity of light in centimeters per second squared. See Glasstone, pages 86-88 for use of other units. Have students compare the amount of energy produced in the above nuclear reaction to the energy produced in a typical chemical reaction; for example, in the burning of one mole of carbon. Then calculate the theoretical loss of mass in this reaction. Be sure that students understand why the law of conservation of mass applies to chemical but not to nuclear reactions. To further illustrate the mass-energy relationship have the students use the $E = mc^2$ equation to find the energy equivalent of the mass of some common object such as a pencil. Ask them to: - Compare this energy with the number of kilowatt-hours of electricity your family uses during a month. How many months would this supply your present needs? - Compare the energy liberated in part "a" to that liberated when an equivalent quantity of the fuel used to heat your home burns. How many times greater is the energy liberated by nuclear conversion than that liberated by chemical action?	Andrews and Kokes <u>University Chemistry</u> Vol. II pp. 525-527 Dull, et al. <u>Modern Chemistry</u> p. 564 Hodgman (ed.) <u>Handbook of Chemistry</u> and <u>Physics</u>

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	If different students select various pieces of electrical equipment and calculate the energy needed to run each for a month, the energy comparisons can be presented in picture graphs suitable for a bulletin board display. Present the information from Glasstone and Gilreath about the various kinds of particles used in producing artificial transmutations. Enumerate the factors affecting the choice of projectile. Show the film "Beyond Uranium" in which a discussion of some of the transuranium elements is presented by the men who first prepared and identified them. "Modern Alchemy" or "Making Elements," the other two films in the series, may be shown instead of "Beyond Uranium." See the bibliography for a brief description of these films. Because of their length it is suggested that all three not be shown to any one class. Give equations for the preparation of some of the trans-uranium elements and ask students to speculate about the possibility of creating elements beyond 103. Consider the amount of original material needed and the half-lives of these elements.	Glasstone <u>Op. cit.</u> pp. 273-284 Gilreath <u>Fundamental Concepts of Inorganic Chemistry</u> pp. 364-372 County Film #590.99 "Beyond Uranium" County Film #590.99 "Modern Alchemy" County Film #590.98 "Making Elements" Gilreath <u>Op. cit.</u> pp. 378-389 Markham and Smith <u>Op. cit.</u> pp. 548-549

CONTENT	TEACHING SUGGESTIONS	REFERENCES
C. Fusion reactions	Have a student report on the development of the hydrogen bomb and the reactions that may occur in it. The carbon cycle is believed to account for the energy of the sun. Ask students to write nuclear equations for each step in the cycle and also the equation for the overall reaction. Point out the catalyst involved, the amount of energy produced, and the time to complete one cycle. Be sure the students understand how fission and fusion reactions differ from each other. As a summarizing activity for the preceding part of the unit, have students write examples of chemical and nuclear changes, indicating exactly what changes are taking place and explaining how a nuclear reaction differs from a chemical reaction.	Scientific American <u>Atomic Power</u> pp. 161-178 Andrews and Kokes <u>Op. cit.</u> pp. 527-528 Gilbreath <u>Op. cit.</u> pp. 376-378 Bradbury, et al. <u>Op. cit.</u> p. 345 Glasstone <u>Op. cit.</u> pp. 440-443 Andrews and Kokes <u>Op. cit.</u> pp. 518-525

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Fission	Have students complete partial equations as in Castka, pages 128-129, problems 2, 4, 5, and 6. Briefly describe or have a student report on the discovery of nuclear fission. Point out that fission reactions are different from the nuclear reactions already studied with respect to the amount of energy produced per reacting atom, the size of the particles produced, and the fact that the type of particle which starts the reaction is also among the products. Write a nuclear reaction for the fission of uranium. Emphasize that this is not the only possible way in which uranium splits. Use the reference in Bradbury or the "Chart of the Nuclides" to show the various isotopes formed in this reaction. Explain the meanings of chain reaction and critical size and tell how these concepts were used to make the first reactor.	Castka <u>Chemistry Problems</u> pp. 128-129 <u>Scientific American</u> Vol. 198, No. 2 pp. 76-84 Dull, et al. <u>Modern Chemistry</u> pp. 572-573 Andrews and Kokes <u>Op. cit.</u> pp. 528-529 Glasstone <u>Op. cit.</u> pp. 385-389, 426-429 Garrett, et al. <u>Op. cit.</u> pp. 435-438 Bradbury, et al. <u>Chemistry and You</u> p. 699 General Electric Company Chart <u>Op. cit.</u>

CONTENT	TEACHING SUGGESTIONS	REFERENCES
IV. Subnuclear particles	Refer students to the table in Garrett to show them that electrons, protons, and neutrons are not the only particles involved in a comprehensive study of the nucleus. *Have high ability students report on subnuclear particles. The references give current developments for this topic.	Garrett, et al. <u>Op. cit.</u> p. 427 <u>Scientific American</u> See bibliography for 7 appropriate articles. Hughes <u>The Neutron Story</u> Semat <u>Op. cit.</u> pp. 431-472 <u>Science and Math Weekly</u> Vol. 1, No. 14 pp. 162-163 Vol. 1, No. 16 pp. 184-185
V. Instrumentation A. Detecting devices	Divide the class into groups to study and complete laboratory activities on detecting instruments as indicated below.	Tyson <u>Atomic Radiation in the High School Science Class</u> pp. 46-47

CONTENT	TEACHING SUGGESTIONS	REFERENCES
1. Electroscope 2. Geiger counter 3. Cloud and bubble chambers	Ask a committee of several students to study the construction and operation of a simple electroscope. Have them design and carry out a series of experiments to compare the rate of discharge from background radiation with that from various radioactive sources placed at varying distances from the instrument. After the students have accumulated sufficient data, have them report to the class describing their experiments and hypothesizing about the results. Suggestions for discharging an electroscope by x-rays and gamma rays are given by Joseph. Borrow the geiger counter from the physics department and teach its operation to an interested student who should report on its construction and demonstrate its use to the class. Other students should report on background radiation and the effect of air, cardboard, glass, sheets of metal, etc. on the absorption of particles. Again, students should be able to predict the inverse square law as described by Tyson. Ask several interested students to investigate and report on cloud and bubble chambers including Wilson's pioneering efforts and the Glaser instrument for which the developer recently was awarded a Nobel prize. In addition to doing library research on the construction, operation, and uses of these devices, students might construct a small alpha-track cloud chamber and a diffusion cloud chamber.	Dull, et al. <u>Modern Physics</u> p. 154 Joseph, et al. A Sourcebook for the <u>Physical Sciences</u> pp. 558-560 Tyson Op. cit. pp. 40-41 Dull, et al. <u>Modern Physics</u> p. 156 Joseph, et al. Op. cit. p. 560 Science and Math <u>Weekly</u> Vol. 1, No. 17 pp. 198-199 Garrett, et al. <u>Chemistry</u> p. 414 Dull, et al. <u>Modern Physics</u> pp. 155-156

CONTENT	TEACHING SUGGESTIONS	REFERENCES
4. Spinthariscopes and photographic film	Various instruments and devices are used to observe and record scintillations. Investigate methods of observation of scintillations with microscopes, the spinthariscopes, and photographic film. Complete laboratory activities as suggested.	Joseph, et al. <u>Op. cit.</u> pp. 563-565 <u>Scientific American</u> Vol. 192, No. 2 pp. 46-50 Dull, et al. <u>Modern Physics</u> pp. 155-156 Joseph, et al. <u>Op. cit.</u> pp. 565-566 Tyson <u>Op. cit.</u> pp. 53-54
B. Bombarding devices 1. Accelerators	Prepare a display showing the various detecting instruments constructed. Include a short report of each model or exhibit and its significance as a detecting instrument. As bombarding devices are studied, their use in producing useful radioactive isotopes should be pointed out. Show the film, "Atom Smashers." Have interested students build models and report on particle accelerators including the Van de Graaff generator, the linear accelerator, the cyclotron, the synchrocyclotron, and the betatron. These instruments are based on the principle that unlike charges attract and like charges repel. Emphasize how this principle is used in accelerating the particles in each instrument rather than the structural details of the instrument itself.	Dull, et al. <u>Modern Chemistry</u> pp. 564-569 Wilson and Littauer <u>Accelerators: Machines of Modern Physics</u>

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Reactors	Have a student report on nuclear reactors. Emphasis should be put on the functions of the various parts: fissionable material, moderator, control rods, and shielding. Indicate what materials are used and why. Discuss the production of fissionable material in a breeder reactor. Explain the difference between the fission reaction as it takes place in the reactor and in the atomic bomb.	County Film #590.55 "Atom Smashers" Glasstone <u>Op. cit.</u> pp. 248-272 Scientific American <u>Atomic Power</u> pp. 3-29 Bradbury, et al. <u>Op. cit.</u> pp. 354-355 Glasstone <u>Op. cit.</u> pp. 460-465 <u>Ibid.</u> pp. 432, 465-466, 437-439 Scientific American <u>Atomic Power</u> pp. 30-33

CONTENT	TEACHING SUGGESTIONS	REFERENCES
C. Separating devices 1. Gaseous diffusion 2. Electromagnetic 3. Centrifugal 4. Thermal diffusion VI. Uses of radioactive isotopes	Ask four students to report on gaseous diffusion, electromagnetic, centrifugal, and thermal-diffusion devices for separating isotopes. In addition to explaining the operation of the devices the students should sit as a panel to compare their usefulness and the difficulties involved.	Glasstone <u>Op. cit.</u> pp. 223-231 Bradbury, et al. <u>Op. cit.</u> pp. 355-356
A. Industrial uses	Radioactive isotopes are constantly being created, studied, and put to widely varied industrial and biological uses. Have students read periodicals and newspaper reports on the uses of isotopes. Since this is an area in which new developments are frequent, it is important that students understand the necessity for locating the latest available information. A few articles are suggested but teacher and students should consult the <u>Readers' Guide</u>, AEC publications and <u>Radioisotopes in Science and Industry</u> for current information. Films from the AEC can also be obtained and used. Have students investigate and report on some of the following topics: 1. The use of cobalt 60 as a thickness gauge 2. The use of barium 140 to detect leaks in pipe lines and to determine the rate of flow of liquids 3. The use of isotopes to improve plastics	<u>Science Digest</u> Vol. 41, No. 5 pp. 94 ff. <u>Newsweek</u> Vol. 50, No. 7 p. 67

CONTENT	TEACHING SUGGESTIONS	REFERENCES
B. Biological uses	4. The use of isotopes to test wax, bearings and castings 5. The use of radioisotopes in tire manufacture 6. The use of isotopes in banking 7. The use of isotopes in the steel industry The following topics are suggested for student reports or class discussion: 1. The use of tracers to study the effect of radiation on living cells; the study of ATP, DNA, and RNA 2. The irradiation of foods and medicines 3. A study of victims exposed to severe dosages of radiation including research reactor accidents and the Japanese victims 4. The use of tracers in agriculture As a culminating activity on the uses of radioactive isotopes show the filmstrip, "Atoms for Peace."	<u>Science News Letter</u> Vol. 72, No. 4 p. 57 <u>Science News Letter</u> Vol. 73, No. 7 p. 105 <u>New Republic</u> Vol. 141, No. 8-9 p. 4 <u>Science and Math Weekly</u> Vol. 1, No. 18 pp. 206-207 <u>Science News Letter</u> Vol. 75, No. 8 pp. 121 ff. Life Filmstrip "Atoms for Peace"

CONTENT	TEACHING SUGGESTIONS	REFERENCES
VII. Problems A. Biological effects of radiation	The discovery of nuclear energy affords great opportunities for improving the human condition but it also presents many new problems. Aside from the possibility of massive destruction in the event of nuclear war, purely peaceful applications of these forces are accompanied by serious hazards. In this section students should be informed of the genetic and somatic consequences of exposure to radiation. Have students report to the class on the following topics: 1. How radioactive isotopes occur in fallout all over the earth 2. Cell damage from ionizing radiation 3. Radiation damage to the total organism 4. Radiation, mutation rate, and evolution 5. Varying estimates of permissible dosages and lethal dosages	Science News Letter Vol. 75, No. 3 p. 150 Newsweek Vol. 54, No. 20 p. 77 Vol. 53, No. 9 p. 57 National Academy of Sciences <u>The Biological Effects of Radiation</u> pp. 3-40 <u>Scientific American</u> Vol. 201, No. 3 pp. 74-83, 84-93, 94-116, 117-137, 138-163, 164-176 Resource Sheet 2 Glasstone <u>Op. cit.</u> pp. 594-599 Science Vol. 128, No. 3402 pp. 417-419
B. Contamination and clean-up 1. Fallout	Explain to the class the importance of determining radiation intensity after a nuclear explosion. Show them a method for calculating the dosage received by exposed persons. *Have a high ability student investigate and report on the use of the Kaufman equation ($K = I \cdot T \cdot A$) for calculating radioactive dosage. (See Suggestion for Independent Study #8.)	

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	Have regular classes use the Fallout Decay Curve on Resource Sheet 2 to find approximate radiation dosages.	<u>Science</u> Vol. 129, No. 3411 p. 1192 Vol. 130, No. 8 p. 443 Vol. 132, No. 3425 pp. 448-454 National Academy of Sciences <u>Op. cit.</u> pp. 41-48 United States Atomic Energy Commission <u>Teaching With Radio- active Isotopes</u> pp. 6-7 <u>Newsweek</u> Vol. 53, No. 6 pp. 34-36 <u>Nation</u> Vol. 188, No. 4 pp. 306-307 <u>Consumer Report</u> Vol. 25, No. 2 pp. 64-70

Have students read and report on some of the suggested references or on some more recent publications concerning the radioactive fallout resulting from the testing or use of nuclear weapons.

CONTENT	TEACHING SUGGESTIONS	REFERENCES
2. Handling of radioactive materials 3. Disposal of radioactive wastes	Review the penetrating power of the alpha and beta particles and the gamma ray. Review also the composition of nuclear reactors and the significance of each component part. Then pose the questions: 1. What precautions should be taken in a laboratory where radioactive materials are being handled? 2. What precautions should be taken to protect the community where a nuclear plant is in operation? Invite a representative of the Martin Company to speak to the class on shielding and handling problems. The lecture by the representative from Martin Company should have introduced the idea of radioactive wastes and at least one method for disposing of them. Ask the students to suggest other methods for getting rid of "hot" waste materials. Then pose the question: "Are the methods we are now using to dispose of radioactive waste materials endangering our health and lives?" In order to have the best available information for answering the question, urge all students to read widely. Select	<u>U. S. News and World Report</u> Vol. 48, No. 1 pp. 60-61 United States Atomic Energy Commission <u>Op. cit.</u> pp. 14-17 Glasstone <u>Op. cit.</u> pp. 599-605 <u>Aviation Week</u> Vol. 71, No. 8 pp. 188-194 Glasstone <u>Op. cit.</u> pp. 605-613 National Academy of Sciences <u>Op. cit.</u> pp. 57-87

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	three students to present a panel discussion based on their reading.	<u>Science and Math Weekly</u> Vol. 1, No. 17, 18, and 19 pp. 194-195, 206-207, 222-223 <u>New Republic</u> Vol. 141, No. 6-7 pp. 5-6 <u>Science Digest</u> Vol. 45, No. 5 pp. 40-42 <u>Nation</u> Vol. 189, No. 8 pp. 144-146 <u>Nation</u> Vol. 189, No. 8 pp. 144-146 <u>Science News Letter</u> Vol. 76, No. 24 p. 401

CONTENT	TEACHING SUGGESTIONS	REFERENCES
	As a summarizing activity for this section of the unit, have the students write a theme on the topic: "What Are the Prospects for the Human Race in the Event of a Nuclear War?"	United States Atomic Energy Commission Op. cit. pp. 18-19

III. Bibliography

A. Books

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Joseph, A., Brandwein, P.F., Morholt, E., Pollack, H., and Castka, J. A Sourcebook for the Physical Sciences. New York: Harcourt, Brace and World, Inc. 1961

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Wilson, Robert R. and Littauer, Ralph. Accelerators: Machines of Modern Physics. Garden City, New York: Doubleday and Company, Inc. 1960

B. Periodicals

"Amateur Scientist," Scientific American 196:159-60+, February 1957

Tells how a young amateur scientist used the carbon-14 method for dating organic materials.

"Atom Agriculture Extends Fruit-bearing Time," Science News Letter 73:105, February 15, 1958

Describes how radioisotopes can be used to vary fruit-bearing time and yields.

"Atomic Beam Performs Brain Surgery on Human," Science News Letter 75:121, February 21, 1959

Discusses one of the beneficial uses of radioactivity.

"Atomic Burying Grounds," New Republic 141:5-6, August 10, 1959

Discusses underground methods of disposal.

"Atomic Energy's Hottest Problem," Science Digest 45:40-42, May 1959

Discusses the biggest problem encountered in the peacetime use of atomic energy.

"Atomic Fallout," Newsweek. 53:34-36, April 6, 1959

Discusses atomic fallout.

"Atomic Radiation Vulcanizes Tires," Science Digest 41:94, May 1957

Discusses radioisotopes in the manufacture of tires.

"A-wastes Stored in Glass," Science News Letter 75:198, December 26, 1959

Discusses one possible solution to the disposal problem.

Barendsen, G.W. and others, "Yale Natural Radiocarbon Measurements," Science 126:908-919, November 1, 1957

Describes special techniques for radiocarbon dating.

Briggs, L.J. and Weaver, K.F., "How Old Is It?" National Geographic Magazine 114:234-255, August 1958

Discusses the application of radiocarbon dating to archeology.

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Discusses the bubble chamber.

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Describes and comments editorially on the disposal of wastes beyond the three mile limit.

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Discusses elementary particles.

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Discusses the level of strontium-90 in the milk supply giving specific levels for different areas of the United States.

Flowers, B.H., "The Structure of the Nucleus," Journal of Chemical Education 37:610-615, December 1960

Considers several nuclear models.

"Food Fit to Eat; Testing for Radioactivity," New Republic 141:4, August 24, 1959

Indicates that foods may be safely preserved using radioisotopes.

Gell-Mann, Murray and Rosenbaum, E.P., "Elementary Particles," Scientific American 197:72-88, July 1957

Discusses and classifies sub-nuclear particles; also available as reprint #213.

Glaser, Donald A., "Bubble Chamber," Scientific American 192:46-50, February 1955

Discusses tracing of subatomic particles in the bubble chamber; also available as reprint #214.

Hahn, Otto, "The Discovery of Fission," Scientific American 198:76-84, February 1958

Reports on the work of Hahn and Strausman on neutron bombardment of uranium nuclei.

Haring, A., et. al., "Radiocarbon Dating up to 70,000 Years by Isotopic Enrichment," Science 128:472-473, August 29, 1958

Gives a modification of the usual methods of radiocarbon dating.

Hawkes, R., "Scientists Study Spacecraft Shielding," Aviation 71:188-194, August 24, 1959

Discusses shielding in spacecraft.

"Isotopes: Money in the Bank," Newsweek 50:67, August 12, 1957

Describes the counting of money by use of isotopes.

Libby, Willard F., "Radiocarbon Dating," Bulletin of the Atomic Scientists 12:280, September 1956

Gives an overall discussion of the techniques for which the author was awarded the Nobel prize.

Libby, W.F. and Loper H.B., "Fallout of Strontium-90; Letters," Science 129:884-885, August 3, 1959

Discusses the pros and cons of the concentration and effect of strontium-90 in the food supply.

Marshak, Robert E., "Pions," Scientific American 196: 84-94, January 1957

Considers the function and properties of pions; also available as reprint #226.

McCourt, G., "Test Case on Atomic Wastes," Nation 189:43-45, August 1, 1959

Discusses the first test of the legality of disposing atomic wastes on public property.

"More Work for Radioisotopes," Business World 95-96, April 16, 1961

Considers the uses of radioisotopes in a variety of fields.

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Considers the biological effects of radiation.

Morrison, Philip, "The Neutrino," Scientific American 194:58-69, January 1956

Gives an account of the search for and the significance of the neutrino; also available as reprint #230.

"New Uses in Medicine, Biology, and Agriculture," Science and Math Weekly 1: 206-207, May 10, 1961

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"Oceanic Atomic Waste Disposal Declared Safe," Science News Letter 76:401, December 12, 1959

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Penman, Sheldon, "The Muon," Scientific American 205:46-55, July 1961

Considers the behavior of the muon.

Puck, Theodore F., "Radiation in the Human Cell," Scientific American 202:142-153, April 1960

Discusses the effect of radiation on the human cell.

"Radioisotopes and Man," I, II, and III, Science and Math Weekly 1:194-195, 206-207, 222-223, May 1961

Discusses hazards, care in handling, and disposal of radioactive materials.

"Radioisotopes Help Weigh Red-hot Slag," Science News Letter 72:57, July 27, 1957

Presents a method for weighing heavy waste products in the steel industry.

"Rays and Bone Marrow," Time 73:71, April 13, 1959

Considers the biological effects of radiation.

"Reply," Nation 188:306-307, April 11, 1959

Replies to the article "Atomic Fallout" in Newsweek on April 6, 1959.

"Safe Areas in the U.S. if H-Bombs Fall," U.S. News and World Report 48:60-61, January 18, 1960

Discusses areas of possible safety in case of nuclear attack.

Schooley, Robert, "Project: Radioactivity in Milk," Science World 6:23-26, September 23, 1959

Describes the project of a student.

Scientific American 201:73-232, September 1959

Devoted to radiation and its effects on man.

Segré, Emilio and Wiegand, Clyde, "The Antiproton," Scientific American 194:34-41, June 1956

Describes the discovery and detection of the antiproton; also available as reprint #244.

Strom, P.O., "Long Lived Cobalt Isotopes Observed in Fallout," Science 128:417-419; 129:1192, August 22, 1958, May 1, 1959

Discusses isotopes of cobalt present in fallout.

Strong, C.L., "The Amateur Scientist," Scientific American 202:189-202, May 1960

Gives suggestions for projects involving isotopes.

"They Survived the Atom; Yugoslavia's Reactor," Newsweek 53:57, March 2, 1959

Considers the biological effects of radiation.

"Tokuyo Maru, Another Lucky Dragon," Science 130:443, August 21, 1959

Describes the effects of fallout.

Wallace, B. and Dobzhanski, "Radiation, Genes, and Man," Nation 190:84-85, January 23, 1960

Concerns the effect of radiation on the mutation rate.

C. Audio-visual aids

1. Films

Atomic Energy (sound, 12 minutes. Free, Central Film Library, Baltimore County Public Schools, Towson Senior High School, Towson 4, Maryland)

Presents the nature of the atom, nuclear fission, nuclear fusion, radioactivity, and the difference between chemical change and nuclear reaction.

Atom Smashers (sound, 12 minutes. Free, Central Film Library, Baltimore County Public Schools, Towson Senior High School, Towson 4, Maryland)

Explains the importance of cyclotrons and describes two other major types of atom smashers, the linear accelerator and the betatron.

Beyond Uranium (sound, 29 minutes. Free, Central Film Library, Baltimore County Public Schools, Towson Senior High School, Towson 4, Maryland)

Shows how some of the transuranium elements are formed and explains the mechanism of the reactions taking place in a nuclear reactor.

Resource Sheet 1

The Belt of Stability

Number of Neutrons

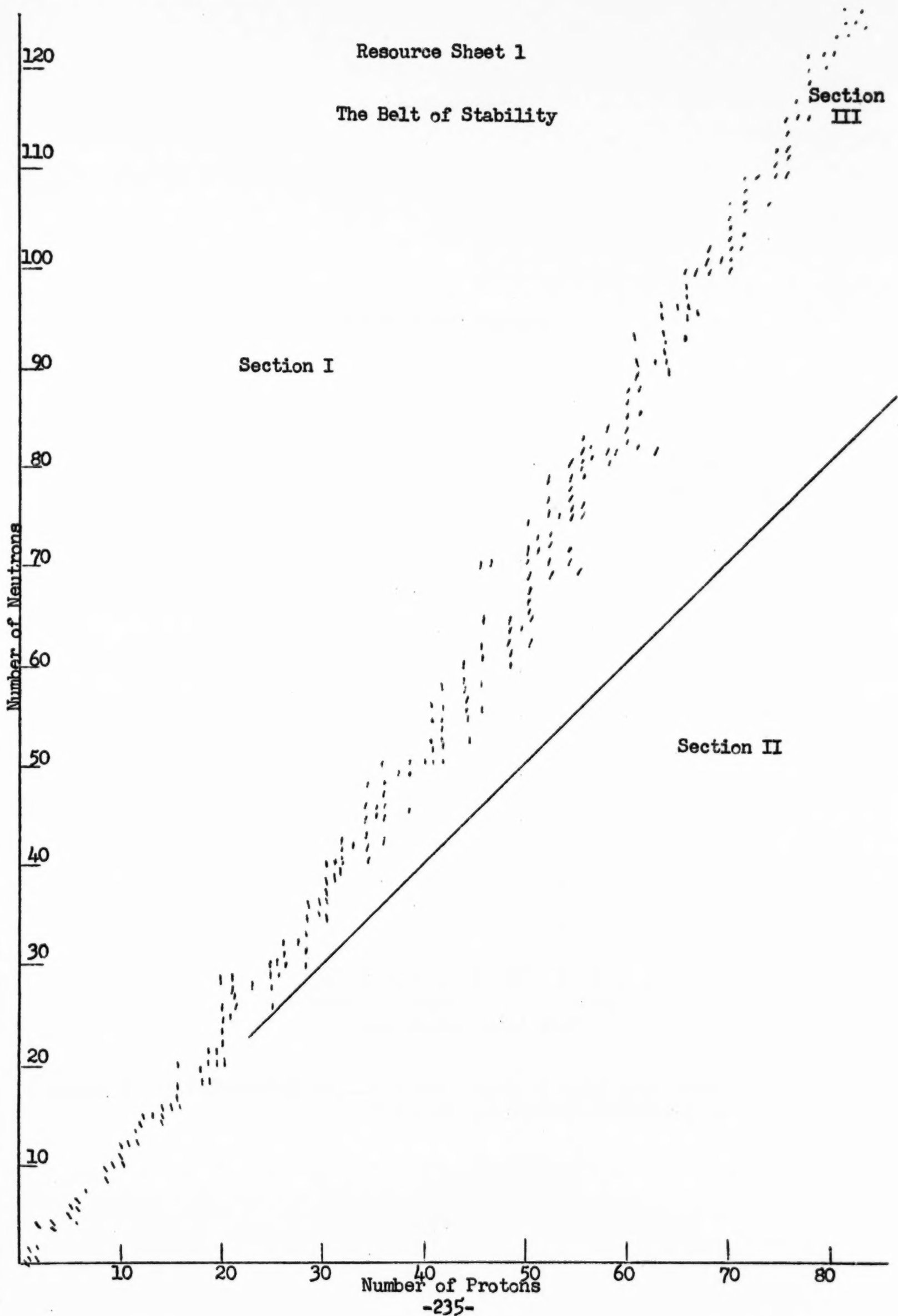
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Section I

Section II

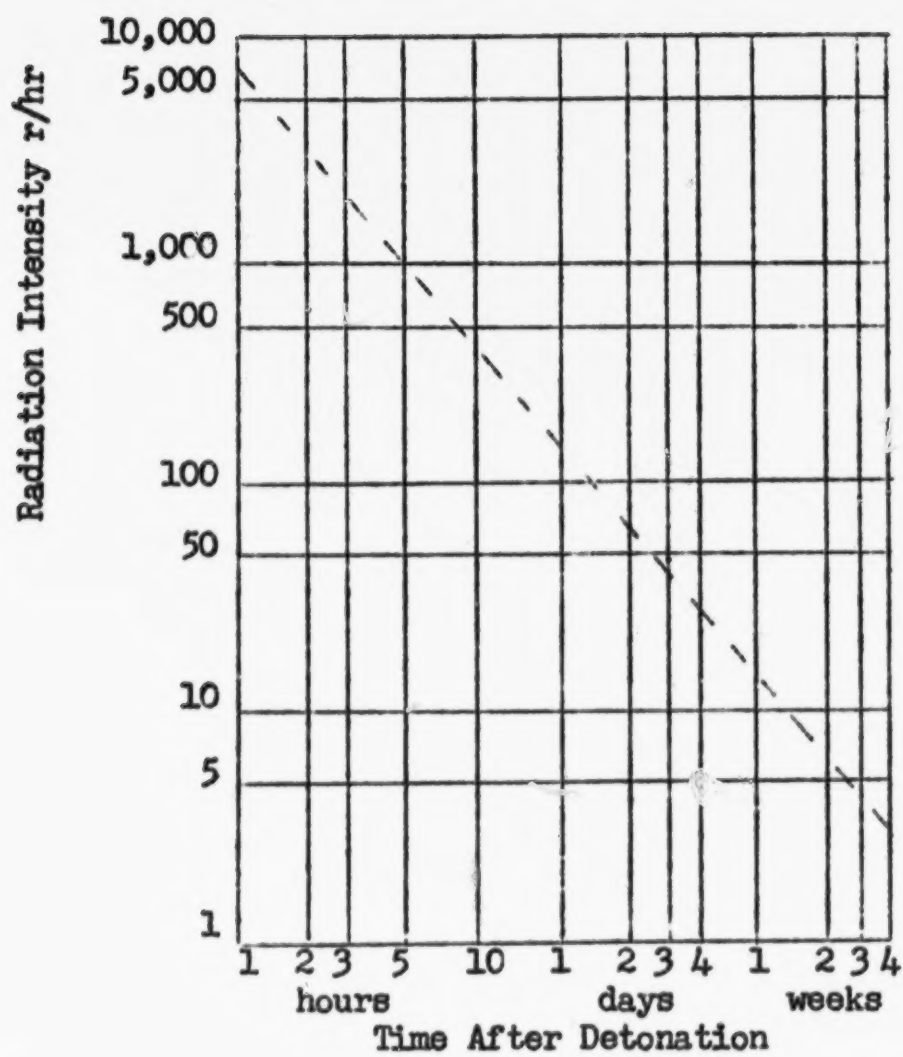
Section
III

Number of Protons



Resource Sheet 2

FALLOUT DECAY CURVE¹



¹ Adapted from Ralph E. Lapp, "Local Fallout Radioactivity", Bulletin of the Atomic Scientists, May, 1951.

Resource Sheet 3

SUGGESTIONS FOR INDEPENDENT STUDY

1. An article in the Scientific American, May, 1960, pages 189-202 gives some suggestions for projects including the use of radioisotopes to determine the thickness of materials and to determine absorption of various elements by plants.
2. An article in Science World, September 23, 1959, pages 23-26 tells how a student determined the radioactivity in milk. His methods of experimentation and organization of data may offer valuable aid to other students interested in doing similar projects.
3. Some of the projects suggested in Atomic Radiation in the High School Science Class pages 52-73 are as follows:
 - a. The demonstration of scattering and absorbing effects of various materials
 - b. The uptake of various elements by plants and animals
 - c. Determination of solubility with radioactive tracers
4. Some of the experiments given in Teaching with Radioisotopes are suitable for student projects. These include the use of radioisotopes in analytical chemistry and radioactive fallout in rain and snow. In addition, at the end of each experiment there are a number of thought questions which may suggest additional projects to the students.
5. Construct a simple dosimeter that will detect major exposure to radiation. Standardize the instrument and use it to detect the presence of radioactive material.
6. Outer space power reactors must be able to withstand high temperatures for long periods of time. Report on the new materials being developed to contain the fuel elements, the suggested radioactive materials, and the most promising cooling methods.
7. Collect samples of radioactive dust and determine the activity to show the amount of radiation in the atmosphere. A filter attached to a vacuum cleaner may be used to collect dust. Four layers of tissue make a suitable film. See Tomorrow's Scientists, September, 1958 for a student's report of his success with this project.
8. Multiple radioactive decay for fission and fusion products may be calculated by use of the Kaufman equation $K=IT^n$ where K =dose rate at unit time measured from time of burst, I =dose rate at any time T measured from time of burst, and n =the Kaufman exponent. The value of n varies with the bomb design, location of burst, and area conditions. For planning purposes

$n=1.2$ is used. Assume the dose rate K one hour after the explosion is 7000 r/hr, a reasonable intensity from published reports.

Note: Sample calculation for part a.

$$K=IT^n$$

$$7000 = 3500T^{1.2}$$

$$2 = T^{1.2}$$

$$\log 2 = 1.2 \log T$$

$$.30 = 1.2 \log T$$

$$.25 = \log T$$

$$T = 1.8 \text{ hours}$$

Refer to the Kaufman equation and the Fallout Decay Curve which were discussed in the section on fallout. Plot a more accurate decay curve that extends the time until the dose rate is reduced to normal background intensity. Do this by using the Kaufman equation as follows:

- a. Calculate I for one month after the burst; use this value for K in the Kaufman equation and calculate I for each of the succeeding months.
- b. Calculate I for one year after the burst and using the equation as above, calculate I for each succeeding nine years.
- c. Substitute normal background intensity in the Kaufman equation and solve for T .

Summarize this information with the entire class. Display these figures and graphs and use them as a basis for a discussion on the dangers and long range effects of nuclear explosions and the need for strict restrictions for the use of any radioactive material.

9. Investigate the amount of waste from nuclear power reactors predicted by the year 2000 and report this in weight, volume, and radiation units. List the present methods of disposal for high-level waste and consider the following questions:
 - a. How do these show promise of meeting the stringent requirements of the problem?
 - b. What drawbacks are evident?
 - c. How do proposed methods for handling the greater amounts of radioactive wastes expected in the future attempt to overcome these drawbacks?

A P P E N D I X

Provisions for Academically Superior and Gifted Students Baltimore County Public Schools

With the unprecedented yearly increases in the numbers of children attending the Baltimore County public schools the heterogeneity of the student body has become more marked and individual differences more sharply defined. Baltimore County has striven to provide for the differences found among the pupils of its system through course selection, through employment of methods of grouping within the grade and within classes, through wide choice of activities within courses of study, through extra or especially designed projects, through individual work with a teacher, and through clubs and student organizations. Programs of study have been built to meet the needs and interests of all pupils. Since pupils do not progress at the same rate, those who learn faster or slower than others have been cared for through such instructional devices as are described above. The increase of numbers in the schools now makes it administratively possible to open new opportunities for improving the ways by which public education can bring each pupil closer to his fullest potential. Science also has helped to this end, for it has recently produced new instruments and techniques by which educators are able to analyze the differences found among pupils, measure them, define their relation to the learning process, and use the results to improve instruction.

This communication is concerned with the improvement of educational opportunities for those boys and girls who are intellectually superior and gifted. Scores on standardized tests, advanced placement in college, scholarships earned in national competitions indicate that the methods hitherto used in widening educational opportunities for these boys and girls have been effective. However, an evaluation of what the schools are doing was in order to see what adjustments would strengthen the program.

In June 1957, the superintendent's staff initiated a study of the intellectually superior and gifted student, and for the next two years, groups of administrators, supervisors, and teachers investigated the problem on national, state, and local levels.

Their investigations carried them into a review of the literature on the intellectually superior and gifted child; into classroom observations, both in Maryland and in other states, to see principles and techniques in action; into deliberations with consultants who are authorities in the field; into an intensive study of the pupil population of the Baltimore County system; and finally, into formulating a set of principles to guide the county personnel in dealing with the local situation.

Of the principles, those most pertinent to the classroom situation treat, first, the identification of the superior and gifted children and establish these criteria upon which selection shall be based. The program shall include

- a. those students with unusually high intellectual capacity (130+ I.Q.)
- b. those students with superior intellectual capacity (120-129 I.Q.)
- c. those students with a school history of high academic achievement
- d. those students with strong motivation for academic work
- e. those students with unusual talent in one or more academic areas

Intellectual traits that are likely to be associated with an academically superior or gifted student are

comprehends abstract ideas

thinks logically, reasons, generalizes

grasps ideas and concepts; synthesizes and organizes

is intellectually curious; interested in thinking

has extensive interests, especially in field of reading

has capacity for creative and imaginative thought

uses scientific methods; compares, analyzes

grasps ideas quickly and learns rapidly

concentrates easily for long periods of time

works readily with symbols

has rich vocabulary

Personal characteristics and attitudes that are likely to be associated with an academically superior or gifted student are

assumes and discharges responsibilities

has sense of humor

is self-critical

likes to work independently

has power of self-motivation

works well with adults and peer groups of own ability

has ability for outstanding leadership

appreciates social values

has capacity for aesthetic appreciation

usually has physical competence

tends to be individualistic

sometimes questions and challenges established conventions and ideas

Secondly, the principles define the role of the teacher in the instructional program and establish some general instructional procedures:

1. The teacher is the most important single factor in the education of superior students, and no program should be offered in a school until teachers fully qualified for the work are available.
2. No teacher should regard his assignment to the special program as permanent.
3. Instructional procedures used with superior and gifted students should be qualitatively rather than quantitatively different from those used with students of average or below-average ability.
4. Care should be exercised to insure in the schedule of the superior or gifted student a balance of intellectual pursuits, leisure-time activities, and participation in the total life of the school, home, and community.

Thirdly, the principles give direction for the organization and administration of the program and establish the premise that adjustments be based upon differentiation within the framework of the general instructional program. Interpretation follows:

1. In the primary grades attention is given to the beginning of the process of systematic and continuous identification of superior and gifted children. Grouping is contiguous, and curriculum guides make suggestions for supplemental work.
2. In the intermediate grades, superior and gifted children are grouped together as nearly as possible, depending upon the number of such pupils in a school. Content areas are enriched. Skill areas are accelerated.
3. In the junior high school, the process of enrichment of content and acceleration of skills continues. As designed, this will enable superior and gifted students to elect Algebra I in grade 8 and Algebra II in grade 9. They may elect to take two years of a foreign language in junior high school beginning in grade 8, provided they agree to continue its study in senior high school. They may elect Biology in grade 9.

These adjustments at the junior high school level enable superior and gifted students to accelerate their programs by taking more advanced offerings in senior high school. Senior high school credit will not be given for foreign languages and algebra studied in grade 8. The student may gain, however, 5 credits toward graduation for work taken in grade 9.

4. In the senior high school, enrichment and acceleration of offerings with additions of honors offerings in grades 10, 11, and 12 and opportunity for advanced courses in grade 12.

The acceptance of the principles and policies just described led to the development of charts outlining the nature of the program at the elementary, junior high, and senior high school levels. For clarification of terms used to describe courses other than the traditional offerings, the following designations should be helpful:

1. An "enriched and accelerated" course is a regular elementary or secondary school offering in which the curricular content is enriched and the skill areas accelerated to make the course profitable for all academically superior and gifted students.
2. An "honors" course designates a regular high school offering that has been re-developed on a higher intellectual level to challenge a group of specially selected students.
3. An "advanced" offering is considered as one that is taught on a college freshman level to a very highly selected group of students.

**Suggested Provisions for Academically Gifted and Superior Students in
Baltimore County Elementary Schools**

Begins the process of systematic and continuous identification of superior and gifted children. Contiguous grouping. Current curriculum guides make suggestions for enrichment and acceleration opportunities in classroom.						
Grades 1 through 3	Language Arts	Social Studies	Science	Mathematics	Foreign Language	Remarks
Grade 4 - Gifted and superior students arranged in sections. (Consideration being given to both ability and achievement.)	Content areas enriched Skill areas accelerated	Content areas enriched	Content areas enriched	Content areas enriched Skill areas accelerated	None	
Grade 5 - Gifted and superior students arranged in sections. (Consideration being given to both ability and achievement.)	Content areas enriched Skill areas accelerated	Content areas enriched	Content areas enriched	Content areas enriched Skill areas accelerated	None	Pupils are expected to maintain "A" or "B" grades in major subject areas
Grade 6 - Gifted and superior students arranged in sections. (Consideration being given to both ability and achievement.)	Content areas enriched Skill areas accelerated	Content areas enriched	Content areas enriched	Content areas enriched Skill areas accelerated	None	Pupils are expected to maintain "A" or "B" grades in major subject areas

**Suggested Provisions for Academically Gifted and Superior Students in
Baltimore County Junior High Schools**

Grade	English	Social Studies	Science	Mathematics	Foreign Language	Remarks
Grade 7 - Gifted and superior students arranged in homogeneous sections.	Enrichment of content and acceleration of skills in core class	Enrichment of content and acceleration of skills in core class	Enrichment of content and acceleration of skills	Acceleration of skills in mathematics	None	Pupils are expected to maintain "A" or "B" grades in major subject areas
Grade 8 - Gifted and superior students arranged in homogeneous sections. Electives in foreign language and mathematics.	Enrichment of content and acceleration of skills in core class (1) (3)	Enrichment of content and acceleration of skills in core class (1) (3)	Enrichment of content and acceleration of skills (1) (3)	Algebra I Mathematics 8 (1) (3)	Latin or modern foreign language <u>First Year</u> (1) (3)	Pupils are expected to maintain "A" or "B" grades in major subject areas
Grade 9 - Gifted and superior students arranged in homogeneous sections with electives in foreign language, mathematics, and science.	Enrichment of content and acceleration of skills in core class (2)	Enrichment of content and acceleration of skills in core class (2)	Biology (2)	Algebra II Algebra I (2)	Latin or modern foreign language <u>Second Year</u> Latin or modern foreign language <u>First Year</u> (2)	Pupils are expected to maintain "A" or "B" grades in major subject areas

- (1) No credit toward high school graduation will be given for these courses.
 (2) Credit given toward graduation. In foreign languages, credit toward academic diploma only if the course is continued for two years in senior high school.
 (3) Parent approval required. Junior high schools would initiate these courses as facilities and personnel become available.

Revised: January, 1961

**Suggested Provisions for Academically Gifted and Superior Students in
Baltimore County Senior High Schools**

Grade	English	Social Studies	Science	Mathematics	Foreign Language	Remarks
Grade 10 - Present practices regarding homeroom sectioning to continue.	*Enriched and accelerated English 10	*Honors World History World History	*Honors Chemistry *Honors Biology Chemistry Biology	*Honors Geometry Geometry Algebra II	Foreign Language III, II, I	*Pupils are expected to maintain "A" or "B" grades in E. & A. and in honors courses in grades 10, 11, 12.
Grade 11 - Present practices regarding homeroom sectioning to continue.	*Honors English 11 English 11	*Honors U. S. History U. S. History	*Honors Chemistry *Honors Physics Chemistry Physics	Trigonometry (1st semester) Algebra III (1st semester) Analytic Geometry (2nd semester) Algebra IV (2nd semester) or other academic mathematics courses	Foreign Language IV, III, II	**Students are expected to meet the standards of the course in advanced offerings. Students may be invited to take those honors and advanced courses which are consistent with their ability, achievement, and motivation in each of grades 10, 11, 12.
Grade 12 - Present practices regarding homeroom sectioning to continue.	**Advanced English English 12	*Honors-Problems of Democratic Living Problems of Democratic Living	**Advanced Science *Honors Physics Physics	**Advanced Placement Calculus or other academic mathematics courses	Foreign Language IV, III	

Parent approval required for placement in honors and advanced courses in grades 10, 11, and 12. Senior high schools will initiate these courses as facilities and personnel become available.

Special weighting in formula for determining pupil rank in class will be given to honors and advanced courses.

Scheduling Suggestions to Secondary Principals

Junior High Schools

Grade 7

- *A. All pupils who have successfully completed the enriched and accelerated work in grade 6 may be recommended for similar classes in grade 7. The junior high school principal and counselors should select from the recommendations of all the feeder elementary schools those pupils they consider qualified to succeed in accelerated and enriched classes in grade 7. These academically able students are then grouped homogeneously for classes in core, mathematics, and science.
- *B. Other pupils who meet the criteria for selection may begin their work in this program.
- C. Articulation must be maintained between the elementary school and the junior high school to make certain that all pupils in this program are properly placed.

Grade 8

- *A. All pupils who have successfully completed the enriched and accelerated work in grade 7 are eligible to continue the program in grade 8. These pupils are grouped homogeneously for enriched and accelerated Core 8. The decision to take Algebra I, Foreign Language I, or enriched and accelerated Science 8 should be determined by (1) the individual pupil's educational aims and by (2) full understanding of the implications of these choices for future educational planning.
- *B. Other pupils who meet the criteria for selection also may begin their work in this program.
- C. Educational aims of pupils need to be given serious consideration in this grade. For example, foreign languages must be continued for two years in senior high school; Advanced Placement Calculus in grade 12 is only possible if Algebra I is started in this grade.
- D. Any one of the following programs may be undertaken after parent approval is obtained:
 - 1. Core 8-Enriched & Accelerated
Science 8-Enriched & Accelerated
Algebra I
Foreign Language I
 - 2. Core 8-Enriched & Accelerated
Science 8
Mathematics 8
Foreign Language I
 - 3. Core 8-Enriched & Accelerated
Science 8-Enriched & Accelerated
Algebra I

Grade 9

- *A. Once again, decisions to take courses in the program for superior and gifted students should be determined by (1) the individual pupil's educational and vocational aims and by (2) full understanding of the implications of these choices for future educational planning.

B. Typical programs in grade 9 for these pupils are as follows:

- | | |
|----------------------------------|----------------------------------|
| 1. Core 9-Enriched & Accelerated | 2. Core 9-Enriched & Accelerated |
| Algebra II | Algebra I |
| Biology | Science 9 |
| Foreign Language II | Foreign Language II |
| 3. Core 9-Enriched & Accelerated | |
| Algebra II | |
| Biology | |

- C. Educational aims of pupils need to be given serious consideration in grade 9. For example, Advanced Science in grade 12 is only possible if Biology is started in grade 9. However, some pupils may need to include Biology in their grade 9 programs, in order to have additional senior high school time for specialization in other subjects.
- D. Because of the demands of this program and those of the elective program, it may be necessary for principals to initiate individual pupil scheduling in this grade.
- E. Articulation between the junior high school and the senior high school is required in order to maintain comparable standards for similar courses at both levels, and also to insure that individual plans of pupils for senior high school are realistic and obtainable.

*Mixed classes composed of some pupils eligible and some ineligible for enriched and accelerated work should not be set up. The number of classes and class size usually can be controlled by becoming more selective in consideration of borderline cases. Exceptions may be necessary in small schools.

Senior High Schools

- A. Articulation between the junior high school and the senior high school is required in order to maintain comparable standards for similar courses at both levels, and also to insure that invitations to "honors" and "advanced" courses go only to the best qualified, highly motivated pupils.
- B. All pupils who have successfully completed the enriched and accelerated work in Core 9 may be placed in enriched and accelerated English classes in grade 10. Pupils who qualify may be invited into Honors English in grade 11 and Advanced English in grade 12.
- C. Parent approval is required for placement in honors and advanced sections.
- D. Usually, students should not be invited into more than one or two honors or advanced sections. However, exceptional students may be able to profit from additional challenges. Schools should make the final decisions in these matters with individual students and their parents.
- E. Principals should consult with supervisors before assigning teachers to classes in this program.

- F. Principals should plan for only as many honors and advanced sections as they can secure highly qualified teachers and students.
- G. Principals should request the assistance from the teachers of the previous grade in making up lists of pupils to receive invitations to honors and advanced sections.
- H. Students interested in Advanced Placement Calculus in grade 12 will need to double in mathematics in grade 11. Their electives at this grade level are:
1. First Semester: Algebra III and Trigonometry ($\frac{1}{2}$ credit each)
 2. Second Semester: Algebra IV and Analytic Geometry ($\frac{1}{2}$ credit each)
- I. Senior high school courses marked "Enriched and Accelerated," (English 10, only) "Honors," and "Advanced" will receive special weighting in the formula for determining rank in class at graduation.

Marking and Grading Practices Relative to the Program for Superior and Gifted Students

If the pupils included in this program are chosen according to the criteria suggested for selection, grading should not be a major problem. Pupils with high ability and high motivation can usually be expected to earn "A" or "B" grades in the program for the academically gifted and superior students because they have had a history of high achievement in their earlier classes.

Elementary School

Pupils in the classes of this program are expected to maintain an "A" or "B" grade in the major subject areas--reading, arithmetic, language arts, and social studies.

Pupils who, over a reasonable period of time, fail to maintain a "B" average in more than one major subject area should be considered for reassignment into a regular group.

The grades of the pupils in this program are determined in the same manner as are the grades of pupils in the regular program. The grade "A" or "B" should be based upon the achievement of pupils generally rather than upon individual school or class achievement.

Junior High School

Pupils in both enriched and accelerated courses and in early elective courses are expected to maintain "A" or "B" grades.

Failure to maintain a "B" average may result in transfer from the course or group and reassignment to a regular section.

The students' grades for courses in the non-elective part of this program are determined in the same manner as are the grades of pupils in the regular program. The grade "A" or "B" should be based upon the achievement of pupils generally rather than upon individual school or class achievement.

The students' grades for elective courses in the eighth and ninth grades are determined in relation to the goals of the course. If the students have been carefully selected, they should be able to maintain "A" or "B" grades.

Senior High School

Students in the enriched and accelerated course and in honors courses are expected to maintain "A" or "B" grades. Failure to maintain a "B" average may result in transfer from the course or group and reassignment to a regular section.

Students are expected to meet the standards of the course in advanced offerings.

The need to maintain "B" or above grades at the senior high school level may cause some students to be reluctant to enter a special course for fear of receiving a grade lower than they might expect to earn in a regular class in the same subject. Parents, too, become concerned. Because admission into high school honors societies and into colleges depends upon high grades, students in competition for college

admission and scholarships are naturally apprehensive when they compete with students from schools in which special grouping is not employed. We do not want to penalize students who accept the invitation to do the challenging work this program provides.

Participation in this program will be noted on the permanent record cards and transcripts of each senior high school participant so that colleges will be aware of all work done in enriched and accelerated, honors, and advanced courses. The symbol "E.A." on these records indicate participation in enriched and accelerated courses. The words "Honors" and "Advanced" indicate participation in these offerings.

In determining a student's rank in class at the approach of graduation, special weight will be given to grades earned in courses marked with a single or double asterisk in the preceding chart on the senior high school program.

The special weightings for courses taken for a full year are:

- A = 5 points
- B = 4 points
- C = 3 points

General Considerations

Pupils who are misplaced should be withdrawn from the program without penalty or embarrassment as soon as evidence is secured to verify such misplacement. For all other pupils, high grades should be considered the natural and normal expectation. If this situation does not result, teachers must be helped to evaluate their marking standards to determine whether or not they are realistic. For this reason it will be necessary for principals, supervisors, and teachers to study the distribution of grades in these classes and to develop reasonable marking standards.

If the school fails to maintain realistic marking practices, pupils may refuse to accept our invitations to undertake the program even though participation is noted on permanent record cards and special consideration is given in determining rank in class.